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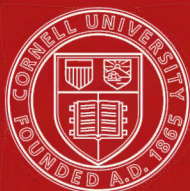
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STUDIES IN ZOOLOGY

AN INTRODUCTION TO THE STUDY OF ANIMALS
FOR SECONDARY SCHOOLS AND ACADEMIES

BY

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STUDIES IN ZOOLOGY.

W. P. 1

PREFACE

THIS volume is not intended to add anything to the science of Zoölogy. It is not for the investigator, it is for the beginner. The author has found that laboratory guides are as a rule too dry and conventional to accomplish the best results and he has accordingly attempted to make these directions simple and suggestive as well as comprehensive. The plan of these studies was worked out in the Manual Training High School, Kansas City, Mo., where it was thoroughly tested with students of all grades of the high school. The book has also been tested in two Normal Schools and in several high schools and has been found to warrant the claims made for it.

Information about animals comes to the child from three sources, viz.: from a study of the animal itself, from a study of the environment, from reference books and lectures by the teacher. This book emphasizes the first and second of these sources and it is expected that the teacher will see that the third is not neglected.

✧ The author has gleaned from so many sources that it would be impossible to acknowledge them all, but he desires to make special mention of the assistance of his associate, Mr. A. N. Young, on the Branch Vermes and on various other parts of the book. All the tables of classification are

credited to their proper authors. The attempt has been made to get classifications that can be understood by the students of the grade in which this book will be used, rather than those intricate tables which can be used only by a trained naturalist.

For any errors in the classifications or in other parts of the book, the author alone is responsible; and the correspondence of his fellow teachers concerning any part of the book which may be improved, is earnestly solicited.

J. A. MERRILL.

State Normal School, West Superior, Wis.

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INTRODUCTION

THAT Zoölogy is an important subject in secondary education, no teacher of culture and experience will deny; but that it has not always met the expectation of those who introduced it into the course, will be admitted by all. Perhaps the cause of this is the difference in point of view between the scientist and the practical educator as to what constitutes the subject matter for a beginner's course. But whatever be the point of view it would seem that the legitimate results of the study of animals at this stage are the training of the powers of observation, a sympathetic appreciation of animal life, and a knowledge of nature's method of producing the changes that are going on daily.

This book is intended to accomplish the results above set forth. It is intended to arouse an interest in the rudiments of Zoölogy, and to put the child in contact with the problems suggested by the animals that surround him. It is not intended that all of these problems are to be solved by the students who use this book, or that all of the questions in the book are to be answered correctly or even definitely, but the student is led to think that with the animals before and around him he should feel free to strive to solve any problem which naturally arises in his mind. The questions are asked in such a way and in such language as to suggest further

thought, and though some of them may appear indefinite, the student is thus led to organize all the knowledge he has and all that he can legitimately obtain toward the answer. A normal child is not content with knowing the structure of an animal nor the comparative structure of several animals; he wants to know how the animals in question use that structure in living. He wants to know how they select and obtain their food, how they treat their fellows, especially those of their own species, and how they successfully overcome the vicissitudes of climate and the onslaughts of their enemies. He delights to look upon the animal world as a struggle for existence—a struggle which requires all the strength, instinct and intelligence which the animal can command. In other words the child prefers to approach Zoölogy through animal ecology, and this book therefore emphasizes the ecological factors in every study. Animal ecology cannot be taught from books, however valuable they may be if rightly used, neither can it be successfully studied from dead forms in the laboratory; but it requires the study of living, active forms not in the laboratory only but in their natural environment. Field trips in which the teacher organizes the work and directs the observation and collecting, will be found of inestimable value and should be taken as often as circumstances will permit.

Dissection of type forms is required in all cases, and should be thoroughly done; but it is regarded as a means of finding how the animal solves certain life problems rather than as an end in itself. The student looks beyond the dissection to the animal's adaptation to its environment, and the dread of dissection with which every teacher has to contend, rapidly disappears.

Comparative anatomy becomes a large part of the study of every form, as each additional animal furnishes a new solution to an old problem. Materials are thus accumulated and the points of structure of greatest value are clustered around the life problems as apperceptive bases.

Classification is the natural outgrowth of comparative anatomy and is given considerable emphasis. The author believes that this has been too much neglected in recent years and that the time has come to reinstate it in a rational way in the courses in Zoölogy. But the required work in classification should consist of an arrangement of the comparisons made from laboratory and field study and need not at this stage include the technicalities of the specialist. However, the use of the manuals of insects and birds may be taught so that students can pursue these delightful studies further if they so desire.

Collections of insects can be made with very little effort and most students at this age are inclined to make them. Such collections, besides the disciplinary value which is great, have a very great value as illustrations of variation and adaptation, the two things which have been prominently associated throughout the work. The laboratory should if possible contain a working collection of insects and birds at least, so that the students may use them in comparing and classifying their own specimens.

This book is not intended to take the place of the teacher, but rather to awaken an appreciation and a demand for the teacher's best effort. It is insisted that the teacher tell the student as little as possible about the things which he can discover for himself, but through all this work the teacher is the guiding spirit and should give to it his most earnest

thought. After the student has done all he can in laboratory and field, lectures by the teacher and references to text-books and library resources, will be found necessary to broaden and deepen the view of the subject.

It is believed that it is not necessary to have a regular text-book in the hands of the pupils to accompany this guide, since the student is thereby led away from his dependence upon nature so strongly insisted upon in every study. If, however, it is thought best to use a regular text the author would recommend *Animal Life*, by Jordan and Kellogg, which is a clear statement of the ecological factors; or *School Zoölogy*, by Burnett, which is a definite presentation of the animal kingdom, including many forms not given in these pages.

The teacher will recognize the value of careful drawing, but it is believed that if students adopt a scale before attempting to draw, the accuracy of the observation will be increased. In many cases this scale has been suggested, and the teacher may encourage the formation of this accurate habit by requiring the scale attached to every drawing.

The observations made under the direction of this book or of the teacher, should be carefully written in a note book in clear, concise language. It is better that the notes and drawing be in ink and that neatness and accuracy be insisted upon from the beginning.

After a study of animals in this way it is believed that students will have a desire to go into the deeper problems of Zoölogy in the College or University.

The course outlined in this book will require about one year's work of one period each day. If the allotted time is shorter, the teacher may adapt this course by omitting cer-

tain forms or certain parts of the anatomy of several forms. The work on insects, for instance, is so arranged that any insect may be taken first and some of the forms may be omitted entirely or the work reduced so that the necessary time may be saved. It is believed that a reasonably thorough study of a few types is better than a superficial study of many types, and that a sympathy with living nature based upon a knowledge of her laws, is of greater importance than a deeper study of anatomy only.

LABORATORY EQUIPMENT

A laboratory properly lighted and equipped adds greatly to the interest and value of the study of Zoölogy. A well lighted and ventilated room on the north side of the building, so arranged as to get but little direct sunlight during working hours is preferable.

The following equipment, which can be obtained at moderate cost, is suggested:

(1) Tables large enough to accommodate four pupils each, with a drawer for each pupil, with slate or plate glass tops. The number of tables would be determined by the number of students to be accommodated.

(2) Compound microscopes, at least two to each table.

(3) A dissecting microscope for each student.

(4) Scissors, scalpel, tweezers, and two mounted needles for each student. (Students can easily mount common needles for this purpose.)

(5) An aquarium large enough to hold twenty to thirty gallons of water. Several smaller ones may be made to answer the purpose.

(6) Slides, cover glasses, jars for holding specimens, and dissecting trays. (Candy trays may be successfully used for dissecting trays.)

(7) A student's microtome and accompanying apparatus.

(8) An insect cabinet, charts, models and a number of forms foreign to the neighborhood, mounted or preserved in alcohol. These forms may be obtained by buying them from supply houses, but the enterprising teacher will be able to get many desirable specimens by exchange with teachers and students in distant localities. The cost of equipping a laboratory for zoölogy need not be great. If the financial condition of the school district make it necessary to economize, ordinary tables or desks may be used, hand lenses will take the place of dissecting microscopes, and glass jars may be used as aquaria.

However, no economy should lead to the attempt to teach zoölogy without compound microscopes and dissecting instruments. Text-book zoölogy is of no value.

REFERENCE BOOKS

There should be a library of reference books for the zoölogy classes consisting of all the standard works; but if such is not possible under existing conditions, the teacher will often be able to get a few volumes. It is better to have a few good books duplicated than to have a miscellaneous collection. The following are recommended and are arranged in the order of their importance:

Jordan and Kellogg, "*Animal Life*."

McMurrich, J. P., "*Invertebrate Morphology*."

Parker and Haswell, "*Text-book of Zoölogy*."

Comstock, J. H., "*Manual for the Study of Insects*."

Lang, "*Text-book of Comparative Anatomy*."

Holland, "*The Butterfly Book*."

Darwin, "*The Formation of Vegetable Mould*."

Jordan, D. S., "*A Manual of Vertebrates*."

Cones, Elliott, "*A Key to North American Birds*."

Tryon, "*Structural and Systematic Conchology*."

DIRECTIONS FOR COLLECTING INSECTS

I. MATERIALS.—At the beginning of his work in Zoölogy the student should provide himself with the following articles and should keep them in proper condition and repair:

(1) A CYANIDE BOTTLE.—This is made by putting a lump of cyanide of potassium, twice the size of a grain of corn, into any wide-mouthed bottle, covering with water and stirring in enough plaster of Paris to make it hard and firm. After this has dried for an hour, put in a piece of cotton and keep the bottle ever afterwards tightly corked.

(2) FORCEPS.—A pair of forceps of steel or wire should be provided for collecting spiders, bumble bees and wasps.

(3) AN INSECT NET.—A net for collecting butterflies and dredging ponds may be made by bending a stout quarter-inch wire into a circle about one foot in diameter, leaving enough at the ends to be fastened on a wooden stick three to five feet long. Over this stretch a flour sack or a piece of mosquito netting.

(4) SPREADING BOARD.—It may be made of two pieces of thin whitewood or pine board, fastened together by braces, especially at the ends, and left wide enough apart to admit the bodies of the insects to be spread; strips of cork or pith, in which to fasten the pins, may then be tacked or glued below so as to cover the intervening space. The

braces must be deep enough to prevent the pins from touching anything on which the stretcher may be laid; and by attaching a ring or loop to one end, the stretcher may be hung against the wall out of the way.—Riley.

(5) MOUNTING PINS AND BOX.—These should be kept handy for mounting the specimens as soon as they are in proper condition.

II. LOCALITIES. (1) ELECTRIC LIGHTS. — Electric lights are so easy of access and provide such an abundance and variety of animals that they are naturally the first fields visited. They should be visited at all seasons from April to November, so that the complete range of specimens frequenting them will be obtained. The most abundant specimens under the lights are beetles; but moths, bugs, grasshoppers, crickets and spiders may also be found there. Collecting is most profitable at the lights during warm, damp (not rainy) nights and it is useless to visit them on a cold, dry night. The beetles will be found under the lights, the moths generally on the post near the lights, the spiders and centipedes in the grass near by.

(2) WOODS.—A profitable place for collecting is also found in the woods or on rocky ledges. Here the insects are more timid and are found under stones or logs, in decayed trees or stumps, or under the bark of decayed trees. The most common forms are beetles, centipedes, several genera of hymenoptera, bugs and spiders. Heavy logs or stones should not be moved since they contain usually no specimens, and the lighter ones should be replaced after the specimens are obtained.

Care should be taken not to injure the specimens in catching them since an injured specimen is worthless.

All the mature specimens found should be taken, since this will furnish an opportunity of exchanging with others, not only of the same class, but with collectors at a distance.

If snail shells are desired the smaller forms will be found in the leaves or in the mosses down close to the rocks.

(3) OPEN PLACES.—This includes prairies and places where the woods are not thick. Such places usually have flowers and other vegetation so that specimens, such as grasshoppers, butterflies, bees, and some forms of beetles are abundant.

The flowers attract the butterflies, bees and sometimes the beetles. For catching them the net is convenient, but care must be taken that the butterflies are not allowed to flutter in the net for fear of spoiling their wings. The best method of killing moths and butterflies is by dropping gasoline over the ventral side of the thorax and abdomen.

The grasshoppers are found hopping or flying over the grass, but some of the smaller forms must be looked for in the leaves or on the fence, the color of which they imitate. Occasionally boring insects are found in dry clay banks on the sides of the roads or streams. It may be mentioned here that some of the most beautiful beetles are found on or near the bodies of dead animals.

(4) PONDS AND STREAMS.—These are explored with the net and are very rich in animal forms. The beetles which swim through and on top of the water, the bugs which glide over and dart through it, and the larvæ of dragon flies which crawl on the bottom of the pond, are found at all times during the collecting season in great numbers. In the spring, fresh-water shrimps, and the eggs of frogs, toads and salamanders are often found. In addition to these,

crayfish are found in all stages of growth during spring and summer. An aquarium to rear and study the forms of life found in the pond, is very profitable as well as interesting.

III. MOUNTING.—As soon as caught the specimens should be put in the cyanide bottle and allowed to remain until they are dead. They should then be taken out of the cyanide bottle and put in a box which contains some cotton. When the collector comes home, the specimens should be removed and mounted.

The butterflies, grasshoppers and bees should have the insect pin thrust through the thorax, leaving one fourth to one third of the pin above the specimen.

They may then be placed in the spreading boards, the wings stretched forward as in flight, and fastened down with strips of paper or cloth pinned at the ends. In this position they should remain until thoroughly dry, the length of time necessary varying from three to ten days.

The beetles should be mounted by thrusting the pin through the right wing cover near the prothorax; while all other insects, as bugs, flies and dragon flies, by thrusting the pin through the thorax.

The specimens may then be placed in a cigar box, or an insect box, which should be neatly lined with white paper, and should contain cork at the bottom, either in sheets or in pieces about one inch square.

When the box is full, two or three moth balls should be placed in it to keep out the insects that infest collections.

IV. NAMING.—After the specimens are properly mounted, they should be named and labeled. The label may consist of a number on a piece of white paper through which

the pin has been stuck. This number should refer to the number in the notebook in which is recorded the name of the family, genus, and species, the sex, the location and date of capture. These data may be supplemented by any interesting items about habits or variations.

The naming of the specimens may be accomplished by the use of Comstock's or Packard's manual of insects.

The characteristics called for by the book should be closely noted to prevent mistakes, and the drawings or pictures in the book should be closely compared with the specimens.

Should the specimens be transferred to a cabinet, the name of the family, genus and species may be placed on a larger card and mounted with the specimen.

Good care should be taken of the collections, and they will always remain objects of gratification and pride.

ARTHROPODS

THE GRASSHOPPER

Melanoplus differentialis

GENERAL APPEARANCE.—Observe the shape, color and size. Measure length and greatest width.

On your drawing tablet make a line of the exact length of the specimen and cross it at the proper place with one as long as the greatest width of the specimen. This diagram represents the longitudinal and lateral axes of the animal.

Lay the specimen down with the *anterior end* (head) from you, the *posterior end* toward you. Note the main differences between the *dorsal* (upper) side and the *ventral* (lower) side. On the ventral side note three well-marked divisions of the body, the *head*, the *thorax*, and the *abdomen*. Do you find these three divisions on the dorsal side? Give reason for your opinion.

What is the nature of the covering? Is it the same all over the body? It is called *Chitin*. Make a drawing of the animal from the left side showing wings and legs in place ($\times 2$).

THE HEAD.—(1) Turn the animal with head toward you. Note the general appearance from front, sides, and top. Study the face. Near the upper part find the large eyes and the jointed *antennae* (feelers). Count the segments in the antennæ. Is the number the same in both? Why? Is there evidence that one has been broken off?

How are the antennæ joined to the head? What kind of joint between the segments?

Above the antennæ near the large eyes look for small eyes or *ocelli*. Look closely for a third *ocellus*. Note the covering of the head. Do you find lines of division? When these lines are deep and extend from one line to another they mark divisions between plates. Do you find plates on the face and sides of the head? How many? The one between the eyes is called the *epicranium*. Follow it backward and forward until you have traced its shape.

Below the epicranium is a bandlike plate, the *clypeus*, and below this is the movable *labrum*, or upper lip. Trace each of these and find the irregularities of surface.

Below each of the large plates is a plate called *gena*, or cheek. Trace these, noting shape and surface. Do the plates now traced cover the entire surface?

Make a drawing of the face showing all the parts named ($\times 3$).

(2) Lift the labrum to see the freedom of motion. Does the living animal move the labrum up or outward? Observe a live grasshopper eating to determine this.

(3) With the scissors or scalpel sever the labrum from the clypeus and remove it. Lay it carefully on a piece of paper outside up.

This exposes two hard, dark colored *mandibles* meeting in the center. Note their method of coming together. Of what use are they? Observe a living specimen to find the direction of their motion. Grasp one firmly with the tweezers and with a quick outward pull remove it. Remove the other in the same way and lay both in proper order below the labrum.

(4) Back of the place where the mandibles were are two pairs of appendages and the *tongue*. Find the tongue between the first pair of mouth parts, lift it up and sever it at the base with the scissors. Lay it back of the mandibles.

The next pair of appendages is the *maxillae*, which must be removed with extreme care. On removing and laying them down they be found to consist of three parts. *a*. The inner part, *lacinia*, black and toothed at the tip; *b*. the spoon-shaped flap fitting over the lacinia, the *galea*; and *c*. the jointed *maxillary palpus* which looks like an antenna. How many segments in it?

All three of these parts are attached to a base called *stipes*. Find all of these parts in each maxilla and lay them in proper position back of the mandibles.

There is still left the *labium* (lower lip). Does it consist of two parts as the pair of maxillae, or of one part as the labrum?

(5) At its base find a ring, or collar surrounding the neck, the *gula*. With the scissors remove the gula with the labium and place it at the posterior end of the group of mouth parts. Find its parts: (*a*) the *submentum* resting on the gula (*b*) the *labial palpi* extending forward from bases called *palpigers*, and (*c*) the lip proper, which is bilobed like the labrum and divided by a lateral line into two parts; the *mentum*, or lower, and the *ligula*, or upper flap.

Count the number of segments in the labial palpi and note their method of attachment at the base.

Make drawings of these mouth parts ($\times 4$).

Label the entire parts by figures and the subdivisions by letters.

THE THORAX.—(1) Remove the wings, that the thorax may be more plainly seen.

Back of the head is the *prothorax*, or collar. Notice its shape on the dorsal and lateral sides. The dorsal side is called *pronotum*. Does it extend around the body? What is the shape of the ventral side? What causes that peculiar structure? It is called *prosternal spine*. Does the prothorax on the dorsal side seem to be divided into segments? How many?

(2) Look carefully at the remainder of the thorax. Is it divided into segments? What indicates the segments? Do they extend all around the body? The segment next the prothorax is the *mesothorax*, and the last one, the *metathorax*. What peculiarity do you notice on the ventral side of the thorax?

(3) The ventral side of the entire animal is called the *sternum*, the lateral side the *pleurum*, and the dorsal side the *tergum*. Note the differences in color and hardness of these parts.

How many legs on the ventral side? Observe the place and mode of attachment to the body. The sockets for attachment are called *coxal cavities*. How many divisions in each leg? In the front pair of legs find the following parts, beginning with the body: *coxa*, *trochanter*, *femur*, *tibia* and *tarsus*, or foot. The tarsus is subdivided into segments. How many do you find? Notice the relative size, shape, and markings of each segment.

Does each pair of legs have the same divisions with the same relative sizes?

When a part of an animal is unusually large or has a peculiar shape for the performance of a special work it is

said to be *specialized*. Do you find any part or parts of the leg specialized? If so, how are the parts specialized and for what purposes?

Make drawings of a first and third leg ($\times 2$). Mark the specialized parts.

(4) Look closely at the sternum of the thorax. How many segments in it? How are they joined together? How does the number of segments compare with the number on the dorsal side? Explain. The three front parts of the sternum are called respectively the *prosternum*, the *mesosternum*, and the *metasternum*.

Make drawings of the sternum of the thorax, showing the first two segments of the legs ($\times 4$).

Study the pleurum of the thorax. Do you find any other markings beside the lines of division?

Look above the second pair of legs, in the groove dividing the mesothorax, and the metathorax for a light colored rough spot. This is a *spiracle* or breathing pore, and is one of the places where air enters the body.

Look at it closely with a magnifying glass in a living specimen and see it open and close as the animal breathes. Look for another one of these on the front side of the mesothorax under the prothoracic collar.

Make a drawing of the left side of the thorax showing the points observed ($\times 3$).

(5) Get a fresh specimen and examine the wings. Move the anterior wings out at right angles to the body. What follows? Why? Note the place of attachment of the front wings. How are they attached? Note the texture of the anterior wings. They are called the *tegmina*, or wing covers. Why should they be called wing covers?

Remove one of the wing covers, being careful to get all of it.

How does its structure compare with the outer covering of the body? Note the strong chitinous tubes running lengthwise the wing and the smaller tubes running from one to the other. How many principal veins do you find? Note that the wing is narrow, dense, and straight.

Beginning with the lower edge of the wing, which is now the front portion, find the large veins as follows: *costal*, the vein nearest the margin, running about two-thirds of the length of the wing; the *subcostal*, a very much larger vein running nearly the entire length of the wing; the *median*, much smaller and soon dividing into two veins nearly equal in size; the *submedian* and *internal* which run close together to the outer margin of the wing.

This divides the wing into three areas: the costal, the part in front of the costal vein; the median, the largest, which lies between the subcostal and the submedian veins; and the internal, the part posterior to the internal vein. Find and locate each.

What seems to be the use of the outer wings?

Make a sketch of the wing cover ($\times 2$).

With the needle or tweezers pull out the inner wings to a position at right angles to the body. How did the size before stretching compare with the wing covers? How does it compare after stretching? Count the number of folds. How do they compare with the tegmina in structure and texture? Do you find the costal, median, and internal areas? How is the wing attached to the body? What makes the inner wing fold up when the animal quits flying? Of what use is the inner wing? Is the animal a good flyer?

Make a drawing of the inner wing slightly folded to show the markings ($\times 2$).

THE ABDOMEN.—(1) Behind the thorax are the movable segments of the abdomen. Move them back and forth to show how they are joined together. How do these joints differ from those in the thorax? Each segment is called a *somite*.

Examine the tergum, the pleurum, and the sternum. How do they differ from the corresponding parts of the thorax? Is the covering of a somite continuous around the body?

Count the segments on the ventral and dorsal sides. Is the number the same? Explain. Count the segments in the abdomen of three individuals. How many on each?

(2) On the segment next the thorax find an indented ear-shaped surface which contains a silvery membrane, the *tympanum*, or ear drum. This is supposed to be the organ of hearing. State the advantages and disadvantages of having it located here.

Look at the pleurum just above the fold for a *spiracle*, or breathing pore. How does it compare with the one on the thorax? Count the number on each side of the abdomen. Is there one for each segment? Is there one on the first segment of the abdomen? If so, where? Can you see these open and close in a living specimen?

Do any of the somites of the abdomen seem to be specialized?

(3) Observe the posterior somites in several specimens. They vary with the sex. The females are more abundant than the males and may be recognized by the presence of four blunt points extending from the ventral side of the last segments of the body.

Get several specimens of each sex.

Study the male first. Count the number of sterna on the ventral side in front of the modified portion. The last sternum is modified into a large convex *subgenital* plate notched on the upper side.

On the dorsal side two additional segments can be seen. The two appendages, the *cerci*, grow out from between the tenth and eleventh segments.

Make a drawing of the abdomen of the male ($\times 2$).

In the abdomen of the female the first seven segments of the sternum are similar to those of the male. Observe that the eighth plate makes the subgenital plate as in the male. On the dorsal side find the ten segments like those of the male. Back of the tenth find another making the sharp tip of the abdomen.

On the ventral side back of the subgenital plate, find the *ovipositor* which consists of six points arranged in pairs. Each pair is pointed posteriorly, but the middle pair, or true ovipositors, which act as guides in placing the eggs, are entirely hidden by the anterior and posterior pairs. These last two pairs are brought tightly together and forced into the ground almost as deep as the length of the abdomen. They are then separated, making a pit into which the eggs are guided by the inner pieces.

Make a drawing of the left side of the abdomen ($\times 3$).

(4) The males of this grasshopper and of many other species makes noises which are supposed to be interpreted by others of the same species. Look on the inner side of the femur of the male for a row of small spines. Examine with lens of dissecting microscope or with hand lens. Draw spines and also the inner side of the femur showing spines.

These spines rub against the outer side of outer wings to produce the sound. Is the noise made when the animal is still or in motion? Give reason. Examine the outer wing under the low power lens of microscope and determine if possible which vein is specialized for noise making. Compare the wing with that of female. Draw specialized wing marking the specialization.

SOME MICROSCOPIC VIEWS.¹—In order to understand better the external structure of the grasshopper it will be necessary to view some parts of it under the microscope.

Cut off a portion of the large eye with a scalpel, turn it over and scrape from it all the black portion leaving it transparent or nearly so. Put this transparent membrane of the eye on a glass slide with the outside up, moisten it with a drop of water, and place on it a thin cover glass. Place this slide on the stage of the microscope in the proper position and observe it with a low power objective. What does this show you about the large eyes? Each of these divisions is called a *facet*. Observe the size and shape of the facet in different parts of the eye. Are they all alike?

Make a drawing of this view.

Cut out a piece of the inner wing from near the center and mount it as the eye was mounted. Observe it with the low power objective. What do those veins now seem to be? Note the different kinds of veins and the structure of each. What do you think the veins are used for?

Make a drawing of this view.

With a scalpel remove from a segment of the abdomen a thin section of the outer skin containing a spiracle. Scrape

NOTE.—For suggestions on how to use the microscope, see Appendix, I.

the inside of this on each side of the spiracle until it is almost transparent. Mount it as before with the outside up and view it with the low power objective. Find a hard circular ridge of chitin inside of which is a thin membrane with an elongated opening in the center, sometimes open but generally closed. The elasticity of this inner membrane allows the animal to breathe. Draw spiracle.

METAMORPHOSIS OF THE GRASSHOPPER.—The eggs of the *Melanoplus differentialis* are deposited in the fall and remain in the ground during the winter. In the spring the larvæ emerge from the openings in the ground scarcely larger than the eggs from which they came. They eat ravenously and as they grow the membranous covering, at first thin and elastic, becomes harder by the deposit of chitinous matter, until the body cannot expand as it grows. The animal then seeks a protected place, the hard shell is burst behind the prothorax, and the animal crawls out of its old, dry, hard skin and begins anew with a soft membrane. After a short period of growth and rapid eating the shell becomes hard again, the animal, considerably larger now, bursts its shell and emerges as before. At about the third molt the wings appear as very small projections from the terga of the mesothorax and metathorax and at about the sixth molt the now fullgrown animal is able to fly.

Get a number of grasshoppers representing the different stages of growth and note the differences in the wings and posterior divisions of the abdomen in three or four stages of the same species. Do you find differences in any other parts of the body?

Make drawings of the left side of three stages showing the differences in form ($\times 2$).

The *Schistocerca americana*, the *Dissosteira carolina* and some others *hibernate* through the winter in the adult state and deposit their eggs in the spring.

INTERNAL ANATOMY.—(1) Get for dissection large freshly killed female specimens of the *Melanoplus differentialis* or *Schistocerca americana*. The largest specimens obtainable will be found most satisfactory. Care should be taken that the specimen be neatly handled and that the parts be removed at the proper time.

After removing the wings, pin the specimen down on a block, or under water, passing pins through the legs and through the posterior end of the abdomen. With the scissors cut through the abdomen on each side at the posterior ends just above the groove in the pleurum and cut forward to the thorax. Lift up the flap thus loosened, being careful not to injure the parts beneath.

Just under the middle of this flap and generally adhering to it find the small elongated tube, the *heart*, or *dorsal vessel*, into which the blood collects from the sides and flows toward the head.

Below the part removed is a layer of *muscles* running both transversely and longitudinally. Remove and examine carefully.

(2) Open the thorax by cutting on the mid-dorsal line up to the head. Pull out the sides and pin them down. Note the strong muscles. Do you find them arranged in bands? Can you trace certain of the muscles to the wings and others to the legs? How many to each? What do the muscles seem to be composed of?

Note the white flaplike bodies, the *air sacs*. Do you find them connected in any way with white lines? Follow the

white lines down to the sides of the body and see if you can find where they stop? They may be connected with longitudinal lines or with the spiracles. The white lines are *tracheae*, or air tubes through which the air is conducted to the body. The breathing apparatus, the spiracles, the air tubes, and the air sacs are called the *tracheal system*. When the animal is living how is the working of this system seen?

(3) The large yellowish masses near the posterior end are the *egg masses*.

The thin membrane surrounding each mass is the *ovary*. Carefully pull the white masses aside and try to find the white tube, or *oviduct*, that leads from them to the ovipositor. Remove the egg masses with the oviducts from the body.

Make a drawing of an egg mass and oviduct ($\times 2$).

Remove one of the eggs from the mass, place it on the slide and without cover glass, examine it carefully by means of the low power.

Do you see a membrane covering the egg?

Are both ends of the egg alike?

Make a drawing of the egg.

(4) The light colored substance between the viscera and the walls of the body is the *corpus adiposum*. Remove some of it and place it on the slide, cover it with a cover glass and observe with low power objective. You may find colorless blood, tracheal tubes which resemble coils of wire, and muscles.

Describe in detail each group that you discover.

Notice how the tracheal tubes branch until the tubes are very small.

Make a drawing of the tracheæ found.

(5) Study next the digestive system. It consists of a long tube, *alimentary canal*, extending the entire length of the body. It is usually dark green in color and occupies the central portion of the body.

With the scissors split the head down to the mouth. The short tube leading back from the mouth is the *esophagus*. Just back of it, in the region of the thorax, the tube enlarges into the *crop*, an elongated receptacle for food. It is sometimes divided into two parts, *ingluvies* the front, and *proventriculus* the hinder portion.

On the side of the crop imbedded in the muscles, find the *salivary glands*, which are grapelike in appearance. They secrete the *saliva*, and pour it into the mouth. Find the ducts leading from the glands to the mouth.

Back of this is a deep construction in which are found the *gastric caeca*, a circle of appendages attached at the sides and having both ends free. How many do you find? What is their shape? The function of these glands is to secrete a digestive fluid similar to the bile of other animals which digests or aids in digesting the foods.

Back of these is the *stomach* proper, which is followed by the *ilium*, cylindrical in shape, but much smaller than the stomach.

Between the stomach and the ilium are great numbers of small white tubes called *Malpighian* tubes which open into the ilium. These act as the kidneys in higher animals. The *colon* is a small tube connecting the ilium with the larger part, the *rectum*, which is found in the ninth and tenth segments reaching the exterior of the body at the *anus*, or vent, at the eleventh segment.

Make a drawing of the entire digestive system ($\times 2$).

THE REPRODUCTIVE SYSTEM.—The ovaries and egg masses of the female have been mentioned but if the time is not favorable so that the eggs are prominent it will be best to study the organs in connection with this subject.

In the female, find the whitish *ovary* on either side of the alimentary canal, and two white *oviducts* leading down to the opening in its ovipositor.

Make a drawing of the ovary and and oviducts ($\times 2$).

In the male, find two elongated whitish bodies, the *testes*, and leading from them the *vas deferens*, two narrow tubes extending to the opening near the arms.

Make a drawing of the testes and the vas deferens ($\times 2$).

THE NERVOUS SYSTEM.—(1) Remove the alimentary canal carefully and notice the white string in the bottom with occasional knots upon it. This is the nervous system and consists of *CORDS* and *GANGLIA*.

(2) Above the esophagus find a large *supra-esophageal* ganglion sending nerves to the eyes and antennæ, and below the esophagus, in front of the prothorax, and *infra-esophageal* ganglion which sends cords to the mouth and forelegs. From the first of these ganglia there are two cords, one passing on each side of the esophagus to the second.

(3) Then find one each in the divisions of the thorax, somewhat larger than the first. These are the *thoracic* ganglia.

Study these and see if you can trace cords to the wings and legs.

Do you find ganglia in the abdominal region?

How many?

In what segments are they?

Make a drawing of the entire nervous system ($\times 2$).

SUMMARY OF STUDY OF GRASSHOPPER.—(1) The grasshoppers are found in open fields and on ground covered with grass or weeds. They are light gray to green and sometimes almost black in color. How many different colors have you found in grasshoppers? How do they compare in size? Are grasshoppers injurious or beneficial? Why? How do they destroy the plant which they eat? How do grasshoppers defend themselves?

(2) What parts of the United States are visited by grasshoppers most frequently?

In Europe, grasshoppers do very little damage, and are in fact, rather scarce. Do you know of any country in ancient times that was visited by them? Why do grasshoppers migrate?

In ancient times in the oriental countries the damaging genus was the *Schistocerca*, but the most devastating genus in America is *Melanoplus*.

Mount as many different species of grasshoppers as you can find.

THE CRICKET

Gryllus sp.

(1) What is the color of the cricket? What is its method of locomotion? What are the principal differences between the general appearance of the cricket and that of the grasshopper?

(2) Turn a cricket from dorsal to ventral side and notice the general shape of the body. How many divisions? How are they separated? Is the body segmented? How many segments in the antennæ? How many legs and where at-

tached? How many segments in each leg? Look on tibia of foreleg, what do you find? Can the cricket hear? How many wings? What are their peculiarities?

(3) On the abdomen of all, find stylets or slender projections. The abdomen of the female ends in a long ovipositor. Pick the ovipositor apart and see if you can find as many parts as were found in the ovipositor of the grasshopper.

(4) The chirping sound of the cricket is made by the male, by rubbing the outer wing over the inner. Look for a cross vein with teeth on it on the under surface of the outer wing which rubs on a correspondingly heavy vein on the inner wing. Watch a living specimen to find how this is done.

Make the following drawings:—

Front of head ($\times 2$).

Inner surface of outer wing showing teeth ($\times 3$).

Inner surface of front leg showing drum on tibia ($\times 2$).

Dorsal view of female ($\times 2$).

THE MEADOW LOCUST

Orchelimum sp. or Conocephalus sp.

Where is this animal found?

Is it more like a grasshopper or a cricket?

Has it any characteristic common to both the others?

In what does it differ from the others?

What is its food? During what part of the day does it travel?

How do the male and female differ? Of what use is such a flattened ovipositor?

Does the meadow locust make a sound? How?

Make the following drawings:

Left side of entire animal ($\times 1$).

Abdomen of male and female ($\times 2$).

THE MANTIS

Do you find the three divisions of the body? What is the length of the longitudinal axis? The lateral? What specializations are noticed in the body? In the head? In the legs? How does the young mantis compare with the old? Does it grow by molting?

Make the following drawings:

A dorsal view ($\times 1$).

The front feet ($\times 2$).

The face ($\times 4$).

CLASSIFICATION.—(1) Animals are classified by collecting their resemblances and differences. Every animal in the world has something in common with every other animal, and these common characteristics enable us to put them into one group called the animal kingdom. This separates them from the other great group of living things called the plant kingdom.

(2) The animals we have studied are different in many things, but we have found that they are alike in a few things. Make out a list of things which have the same structure in all the animals studied. Then make out a list of differences in the same way.

Arrange them in a tabulated form as follows:

Comparison of grasshopper, cricket, locust and mantis, etc.

SIMILARITIES.

Names of things that are similar.	Shape and covering of body.	Body Divisions.	Legs.	Wings.	Respiration.	Nervous System.
Structure common to all.	Elongated, Covered with Chitin.	Head, Thorax and Abdomen.	Three pairs, segmented.	Two pairs; outer straight, inner folded.	By Tracheae.	Double cord and ganglia on ventral side.

The items of similarity enable us to put these animals into one order (group) called *Orthoptera*. What does the word mean? When we use the word *Orthoptera*, we know that it includes not only all the animals that we have studied, but all others that are possessed of these same characteristics.

DIFFERENCES.

(3) In like manner we arrange the points that are different.

An. Studied.	Pts. of Dif.		Thorax.	Legs.	Abdomen.	Name of Family.
	Antennae, etc.					
1. Grasshopper.	Short, blunt, etc.		Flat, broad beneath.	Third pair highly specialized.	Ends in four blunt points.	Acrididae.
2. Cricket.						
3. Meadow Locust.						
4. Mantis.						
5. Mantis.						
6. Cockroach.						

(4) Since these animals are different in all these characteristics we separate them into groups called *families*. This enables us to refer to them more definitely. The grasshopper belongs to the family *Acrididae*, the cricket to the family *Gryllidae*, the locust to the *Locustidae*, and the mantis to *Mantidae*. These names may be put into the diagram to the right of the double line. The names of families usually end in *dae*.

(5) The grasshopper, we have found, belongs to the order Orthoptera and the family Acrididae, but since there are a great many kinds of grasshoppers we are not yet able to refer definitely to any one kind. Therefore a further classification is necessary. We divide the family into *genera* and the genera into *species*. Thus the grasshopper we studied belongs to the genus *Melanoplus* and to the species *differentialis*; the cricket belongs to the genus *Gryllus*, *species domesticus*, etc. When we use *Melanoplus differentialis* we refer to a species of grasshopper all of the individuals of which are alike wherever they may be found.

(6) If we wish to locate a person where others may be able to find him, we must give his country, state, county, city, street, number on street and name; likewise if we wish to classify an animal so that one may locate it, we must give its kingdom, branch, class, order, family, genus and species.

So we see that finding the names of animals is somewhat like finding people.

(7) The order Orthoptera comprises six common families:

Acrididae, or grasshoppers.

Gryllidae, or crickets.

Blattidae, or roaches.

Mantidae, or mantises.

Locustidae, or locusts.

Phasmidae, or walking sticks.

If possible, find a sample of each and mount according to directions.

NOTE.—The walking stick and the cockroach, if easily obtained, should be examined for external characteristics.

Directions for using the tables of classification are given in the Appendix, II.

CLASSIFICATION — FROM COMSTOCK.

Table of Families of Orthoptera.

A. Posterior femora fitted for walking, *i. e.*, resembling those of the other legs; ovipositor with the subgenital plate concealed; organs of flight of immature forms in normal position; insects mute.

B. Anterior wings leathery, very short, without veins, meeting in a straight line; posterior wings, when present, folded to the middle of the anterior margin; tarsi three-jointed, the pulvillus wanting; cerci horny, resembling forceps. *Forficulidae*.

BB. Anterior wings parchmentlike, thickly veined; posterior wings folded to the base; tarsi five-jointed; cerci soft, jointed or without joints.

C. Body oval, depressed; head wholly or almost wholly withdrawn beneath the pronotum; pronotum shieldlike, transverse; legs compressed; cerci jointed; rapidly running insects.

Blattidae.

CC. Body elongated; head free; pronotum elongated; legs slender, rounded; cerci jointed or without joints; walking insects.

D. Front legs fitted for grasping; cerci jointed.

Mantidae.

DD. Front legs simple; cerci without joints. . . . *Phasmidae*.

AA. Posterior femora fitted for jumping, *i. e.*, very much stouter or very much longer, or both stouter and longer than the middle femora; ovipositor horny, free (except with the Mole crickets); organs of flight of immature forms inverted; stridulating insects.

- B. Antennae short; tarsi three-jointed; supposed organs of hearing situated in the first abdominal segment; ovipositor short, composed of four separate plates; stridulating organs situated in hind femora and the costal area of the tegmina. *Acrididae*.
- BB. Antennae long, setaceous; tarsi four or three-jointed; supposed organs of hearing situated in the anterior tibiae, and also in the prosternum; ovipositor elongated (except in the Mole crickets); composed of four connate plates.
- C. Tarsi four-jointed; ovipositor (when exerted) forming a strongly compressed, generally sword-shaped blade; the stridulating organs of male limited to the anal area of the tegmina. *Locustidae*.
- CC. Tarsi three-jointed; ovipositor (when exerted) forming a nearly cylindrical, straight, or occasionally up-curved needle; the stridulating organs of the male extend across the anal and median areas of the tegmina. *Gryllidae*.

THE BUTTERFLY

EXTERNAL FEATURES. — The cabbage butterfly (*Pieris rapae*) or the yellow sulphur butterfly (*Eurymus philodice*) are suitable specimens for study. Gather several from the open places or gardens and note the flowers on which they feed.

(1) Observe the distribution of colors over the body. Do you find a definite arrangement of colors?

Do you find the three divisions of the body? What are the characteristics of each?

(2) Notice the shape and length of the *antennae*; how many segments? On the lower side of the head find the coiled *proboscis*, or *tongue*. Uncoil it with a needle or with the tweezers. The tongue is made of the galeae of the maxillae.

On each side of the proboscis find a feathery *labial palpus*.

Note the eyes. Do you find simple eyes? How many pairs of legs? For what are they used? Does the butterfly walk?

(3) Note the *wings*. How many? Where attached? For what are they used? Do you find a backward extension of the mesothorax consisting of two parts? These are the *patagia* or wing lappers.

How many segments in the abdomen?

(4) Make the following drawings:

- (a) Drawing of left side with wings folded ($\times 2$).
- (b) Drawing of dorsal side with wings expanded ($\times 2$).
- (c) Scrape powder off of wing and draw (high power).
- (d) Scrape down off of body and draw (high power).

WINGS OF THE BUTTERFLY.—(1) Get a specimen of the *Anosia plexippus** and remove the wings. Note the differences in shape between the outer and inner wings. Do you find any peculiar markings on them? The stripes indicate the position of the veins. How are they arranged? Do they look like those of the grasshopper?

(2) The front margin of the wing is the *costal* margin; the one farther from the body is the *outer* margin, and the one below is the *hind* margin. The first front vein is the *costal*, the second is the *sub-costal*, the third is the *radius*. Under this in the part near the body is a large cell without veins, called the *disk*. On the outside of this cell runs the *media* divided into three divisions. Below the cell is the *cubitus* which is also subdivided. The last vein is the *anal* vein.

*NOTE: This is the large brown butterfly with black veins on the wings. It is common everywhere.

Draw inner and outer wings ($\times 1$).

DEVELOPMENT OF BUTTERFLY.—(1) Why is the cabbage butterfly so called? Where are the eggs placed? What does it look like when it is first hatched? The young is called a *larva*. Does it molt like the grasshopper? Why do you think so? Is the larva injurious?

(2) Between the larval and the adult stages, the cabbage butterfly passes through a state of complete inactivity. When the larva is through growing, it crawls into a quiet place, assumes a hard brown coat, and is called *pupa*, and after a short time emerges as a full grown butterfly, *imago*. Get some specimens of larvae, put them in a box or jar covered in a way that will allow air to enter, feed them on cabbage leaves and notice the stages of development. Note especially how the pupa is suspended from the object to which it is attached.

(3) In the larva notice the small *web* that comes out under the head. It is spun by the modified labium. Of what use is the web?

Make drawings of the larva and pupa ($\times 2$).

HABITS.—Why do butterflies go to flowers? Why do they go to cabbages? Of what use to them are their colorings? How do they defend themselves?

Do butterflies move about on cloudy days? Where do they stay on such days? Where do they stay at night?

THE MOTH

Phlegethontius celeus

I. THE LARVA.—The larva of the *Phlegethontius celeus* is the common so-called tomato worm. They may be collected

in July or August and preserved in alcohol or formalin, but it is more satisfactory to get them fresh from the vines if they can be found at the time the study is in progress.

Other examples of the same family (Sphingidae) are the tobacco worm, and the vine dresser found on grape vines. These will answer all purposes for the study fully as well as the tomato worm.

EXTERNAL FEATURES.—(1) Can you distinguish body divisions? What is the color of the specimen? Is this color an advantage? Why? What common name is applied to this larva?

(2) What cephalic plate is present in the middle of the face? Do the antennae resemble the legs? Compare the antennae with those of the imago.

(3) What kind of mouth parts has the larva? What kind has the imago? Note the bi-lobed *labrum*. Draw. Behind the labrum find the horny *mandibles*. Notice the *maxillae*, and *labium* behind the mandibles. Draw the labium and maxillae, posterior view.

(4) Find the true legs, and from them determine the segments of the thorax. Are all the true legs alike? What is their function? Draw. ($\times 4$).

Draw entire specimen ($\times 1$).

(5) Count the false legs, or *pro-legs*. What segments of the body bear them? Draw your finger over the tips of the false legs. What happens? Why? For what are these legs adapted? Draw a pro-leg enlarged.

(6) Compare a true and a false leg. Why are the false legs so called? Are they segmented?

(7) Count the segments of the abdomen. How many *spiracles*? How distributed? Draw a spiracle enlarged.

INTERNAL STRUCTURE. — (1) Pin the caterpillar ventral side down, in a dissecting tray, by placing a pin just behind the head and another through the last segment of the abdomen. Make an incision on each side about midway between the rows of spiracles and the mid-dorsal line. Raise this dorsal strip, being careful not to injure the parts beneath, and cut it off.

(2) This exposes the *transverse muscles*. What motion do these muscles produce?

(3) Just beneath the transverse muscles find the *longitudinal muscles* of the dorsal side. Contraction of these muscles produces what motion?

(4) Separate the above muscles; find beneath a whitish, stringlike organ, the *heart*. Trace it from anterior to posterior end.

(5) On either side of and below the heart, extending from the posterior end of the body to the thorax find the delicate, yellowish-white coiled tubes, *uriniferous* or *Malpighian tubules*. These rest on the alimentary canal. They are probably analogous to kidneys.

(6) On either side of the alimentary canal find fan-shaped groups of nearly colorless cords. Note that these cords converge towards the spiracles. They are *tracheae*, or air tubes. Remove one of the groups of tracheae with its spiracle and examine with a microscope. Note the coils of chitin. Draw.

(7) Beneath these fan-shaped groups find longitudinal cords, similar in structure to tracheae, next to the wall on either side. These are the *longitudinal tracheal trunks*. How many?

(8) Make a diagram showing the above features ($\times 2$).

(9) Trace the alimentary canal to the mouth and find the *esophagus*, or *gullet*, and the *crop*. Note a cluster of *salivary glands* around the crop. Behind the crop find the stomach and intestine. Find the posterior opening of the intestine, the *anus*. Draw the alimentary canal as seen from above.

(10) Remove the alimentary canal with extreme care. Note the longitudinal muscles. What is their function? Below and between these muscles note a small white cord with enlargements. This is the *ventral nerve cord*. The swellings are *ganglia*. At the anterior end the nerve cord divides, forming a collar about the esophagus and a ganglion above it. Is there a ganglion in each segment?

(11) Make a diagram of nervous system enlarged ($\times 4$).

(12) Upon what does this animal feed? At what time of the year does it live?

(13) Is it injurious? Why do you think so?

(14) This larva, like the larva of all other insects, is a ravenous eater, and as it grows it molts its skin to make room for its rapidly increasing size.

After molting the last time it goes into the ground arrayed in its pupa covering, a dark brown skin.

II. THE PUPA.—()1 Look for pupae in the gardens where tomatoes have been grown. They may be found in October about four to eight inches under ground. Study the head, thorax, and abdomen of a pupa. Do you find a *proboscis* present? In what condition is it? Do you see any indication of wings? Where?

(2) Is the animal living? How does it obtain food? Does it breathe? Give reasons for your answer.

(3) Draw specimen of pupa ($\times 1$).

III. THE IMAGO.—(1) Observe the general shape of the body. Which animal studied is it most like? Compare it with the cabbage butterfly in size and shape of abdomen, wings and feet. Note carefully the color and markings on wings and body.

(2) Has it a distinct *head*? What parts are present? Are the *antennae* segmented? Measure length of antennae and compare with length of body. Note the position and size of the eyes. Are they compound? In what way do they differ from the eyes of the grasshopper?

(3) Uncoil the *proboscis* and measure its length. How does it compare with the length of the body? Is the proboscis in one piece? Of what mouth parts do you suppose it is composed? Let the proboscis recoil loosely.

(4) Make drawings of dorsal view of entire animal ($\times 1$). Draw axes.

Make the following drawings from microscopic views:—

The compound eye.

A side view of the proboscis.

A cross section of the proboscis.

Remove some of the covering from the thorax, from the abdomen and from the wings and draw each separately.

(5) On the mesothorax find a pair of thin flaps extending back over the base of the first pair of wings. These are the *patagia*, and are an extension of the front of the mesothorax. Do you think they are useful?

Rub the scales off the wings so that the veins may be seen. Study the veins closely and compare them with those of the *Anosia* butterfly.

Draw wings showing veins ($\times 1$).

(6) The feet of the male are very strong and have sharp spurs growing from the tibia. Draw one of the first pair of legs ($\times 1$).

The butterfly and moth with all their kindred families belong to the order Lepidoptera. Find the meaning of the word.

CLASSIFICATION. From A. E. POPENOE.

Table of the Principal Families of Lepidoptera.

SECTION 1. *Lepidoptera Rhopalocera*. Butterflies. Antennae filiform, tipped with a knob or club.

A. Having six feet fitted for walking.

B. Wings broad, rounded, closed back to back, and erect in repose.

C. Secondaries tailed.....Swallow tails, *Papilionidae*.

CC. Secondaries not tailed.

D. Colors white or yellow, marked with black....*Pieridae*.

DD. Colors blue or coppery.....*Lycaenidae*.

BB. Wings narrow, stout, triangular, spread or thrown far back in repose; antennae often hooked.....*Skippers*, *Hesperiidae*.

AA. But four feet adapted to walking, anterior part imperfect.

E. Club of antennae not flat; secondaries of male with raised black spot on a vein.

Milkweed butterflies, *Danaidae*.

EE. Club of antennae flat; colors various...*Nymphalidae*.

EEE. Club of antennae flat; colors nearly uniform, smoky or leaf-brown; secondaries with eye-spots; base of veins in primaries inflated.....Meadow browns, *Satyridae*.

SEC. 2. *Lepidoptera Heterocera*. Moths. Antennae various, not clavate.

A. Body stout, large, spindle-shaped; wings narrow; secondaries about half as long as primaries; antennae prismatic.

Hawk moths, "humming birds," *Sphingidae*.

- B. Size small; bodies wasplike; wings more or less transparent; day fliers.

Peach borer, ash borer, squash borer, *Aegeridae*.

- C. Size medium; head large, free; antennae filiform or pectinate, sometimes slightly clavate.....*Zygaenidae*.

- D. Body large or medium, thick, wooly; head small and sunken; antennae pectinate, more or less, and placed higher on the head than usual...Spinners, silk worms, *Bombycidae*.

- E. Body thick; thorax and abdomen often with dorsal tufts; antennae setiform or slightly pectinate; wings folded rooflike in repose....Cut worm moths, *Noctuidae*.

- F. Body slender; scales fine; wings broad, thin, spread out flat in repose; antennae usually pectinate; palpi small.....Span worms, *Geometridae*.

- G. Palpi in most species long and compressed, beaklike; wings deltoid in repose, or in some rolled around the body.....*Pyrallidae*.

- H. Small moths; palpi short, beaklike; fore wings (primaries) oblong, with a prominent "shoulder," and crossed by bands which are sometimes metallic.

Leaf rollers, *Tortricidae*.

- I. Size small or minute; antennae long, setiform; wings pointed, heavily fringed on posterior margin.....Fur and grain moths, *Tineidae*.

- J. Primaries narrow, bifid or trifid; secondaries trifid.....Plume moths, *Pterophoridae*.

The moths are sometimes called "nocturnals," or night fliers, with the exception of *Sphingidae*, which fly in twilight or daytime, and *Aegeridae*, which fly by day.

The butterflies, on the other hand, are called "diurnals," as they fly only by day.

The *Lepidoptera* are to be esteemed as injurious insects. The only exception is the silkworm, which is, like the others, a plant feeder.

For tracing butterflies and moths to their genera and

species the student is referred to "A Manual for the Study of Insects," by Comstock, or to "The Butterfly Book," by Holland.

THE SQUASH BUG

Anasa tristis

Where is this animal found? Is it injurious? At what time of the year is it most abundant? Do you find the three divisions of the body? What are the most peculiar characteristics of the specimen as you view it from the dorsal side; from the ventral side? Measure the length and width. Draw axes.

THE HEAD.—(1) Look closely for the parts of the head commonly found in insects, viz.: *Eyes, ocelli, and antennae*. How many ocelli? How many segments in the antennae?

(2) On the ventral side raise the sharp, jointed *beak* or *proboscis*. How many segments has it? It is composed of a combination of mouth parts specialized. Of what use can this specialization be? Can you distinguish the different mouth parts?

(3) Find the *labrum* at the base of the proboscis. Lying in a groove on the upper part of the beak are two pairs of hairs. Lift them up with a needle. The shorter pair represent the *mandibles*, and the longer, the *maxillae*.

(4) The sheath which remains is made up of the *labium* and the *labial palpi*. This accounts for the segments found in it.

For what is the proboscis used? How does the animal obtain its food? What is its food?

THE THORAX.—(1) Observe the relative sizes of the

different divisions of the thorax. What is the shape of the prothorax?

Note the numbers and places of attachment of the legs. Are all the segments of the legs present? How many segments in the tarsus? How is the leg used?

(2) Between the middle pair of legs and the wings find on each side a small rough surface almost round. Look near it for a small opening, the *osteole*. From this osteole exudes the offensive odor common to the squash bug. When the fluid leaves the body it evaporates on the granular space. Can this specialization be of any benefit to the animal?

(3) How many wings? Lift up an outer one and study its texture, shape and the way it lies on the body. Contrast the position of the outer wings when at rest with those of the grasshopper. These outer wings are referred to as *half wings*, can you tell why? Observe the inner wings, What are their size, color and texture?

(4) With a needle pull one outer and one inner wing out at right angles to the body and draw the dorsal view of the body ($\times 2$). In this drawing locate the eyes, antennae, and the base of the beak.

THE ABDOMEN.—Count the number of segments on both dorsal and ventral sides. Do you find spiracles? Where and how many? Draw ventral side, showing osteole and beak ($\times 2$).

DEVELOPMENT.—(1) How does the young squash bug compare with the old one in appearance?

Is the metamorphosis complete or incomplete? Get a number of specimens and raise them to maturity. Draw them in various stages.

(2) This specimen and others with similar outer wings belong to the order *Hemiptera*. Can you tell why? Is it an appropriate name?

HABITS.—What animal similar to this is a pest to the farmers? How does it injure crops? Name other examples of bugs that are injurious to people.

Are squash bugs very abundant? What do they depend upon for protection? Have you ever seen them eating? Are they difficult to find? Do you think they possess much intelligence? Why? How do they spend the winter?

What measures could be used to prevent the ravages of the chinch bug.

CLASSIFICATION—ADAPTED FROM COMSTOCK.—All bugs belong to the Order Hemiptera. The Order is divided into two great groups, Heteroptera and Homoptera.

Principal Families of Heteroptera.

A. Antennae shorter than the head, and nearly or quite concealed in a cavity beneath the eyes.

B. Hind tarsi without claws.

C. Fore tarsi flattened with a fringe of hairs on the edge, and without claws; head overlapping the prothorax:...*Corisidae*.

CC. Fore tarsi of the usual form, and with two claws; head inserted in the prothorax.....*Notonectidae*.

BB. Hind tarsi with two claws.

C. Caudal end of the abdomen furnished with a respiratory tube composed of a pair of grooved, threadlike organs.

Nepidae.

CC. Caudal end of abdomen without respiratory tube.

D. Legs flattened, fitted for swimming; caudal end of the abdomen furnished with a pair of straplike appendages (these appendages are retractile, and are frequently withdrawn from sight).....*Belostomidae*.

- AA. Antennae at least as long as the head, usually free, rarely (Phymatidae) fitting in a groove under the lateral margin of the pronotum.
- B. Body of various forms, but, when linear, with the head shorter than the thorax.
- C. Last segment of the tarsi more or less split, and with the claws inserted before the apex.
 - D. Body usually elongated; prothorax narrow; beak four-jointed; second and third pairs of legs extremely long and slender*Hydrobatidae*.
 - DD. Body usually stout, oval, and broadest across the prothorax; beak three-jointed; legs not extremely long.
 - Velidae*.
- CC. Last segment of the tarsi entire, and with the claws inserted at the apex.
 - D. Antennae four-jointed.
 - E. Wing covers of various forms or absent, but not resembling network.
 - F. Beak three-jointed.
 - G. Wing covers when well developed, with a cuneus; those forms in which the adult has rudimentary wing covers have no ocelli.....*Acanthiidae*.
 - GG. Wing covers when well developed, without a cuneus; those forms in which the adult has rudimentary wing covers have ocelli.
 - H. Ocelli wanting.
 - I. Body linear.....*Emesidae*.
 - II. Body greatly flattened.....*Aradidae*.
 - III. Body of ordinary form.....*Reduviidae*.
 - HH. Ocelli present, though sometimes difficult to see.
 - I. Beak very long, reaching to or beyond the intermediate coxae.....*Saldidae*.
 - II. Beak not reaching the intermediate coxae.
 - J. Front femora somewhat thickened, but much less than half as wide as long....*Reduviidae*.
 - FF. Beak four-jointed.
 - G. Front legs fitted for walking.

- H. Wing covers with cuneus. Membrane with one or two closed cells at its base, otherwise without veins *Capsidae*.
- HH. Wing covers without cuneus. Membrane with four or five simple or anastomosing veins arising from the base; or with a large number of veins arising from a cross vein at the base.
- I. Ocelli wanting; membrane with two large cells at the base, and from these arise about eight branching veins *Pyrrhocoridae*.
- II. Ocelli usually present.
- J. Head with a transverse incision in front of the ocelli, which are always present. . *Berytidae*.
- JJ. Head without transverse incision.
- K. Membrane with four or five simple veins arising from the base of the membrane; the two inner ones sometimes joined to a cell near the base *Lygaeidae*.
- KK. Membrane with many, usually forked veins, springing from a transverse basal vein. *Coreidae*.

D. Antennae five-jointed.

E. Scutellum nearly flat, narrowed behind.

F. Tibiae unarmed or furnished with very short spines. *Pentatomidae*.

The Principal Families of the Homoptera.

- A. Beak evidently arising from the head; tarsi three-jointed; antennae minute, bristlelike.
- B. With three ocelli, and the males with musical organs. Usually large insects, with all the wings entirely membraneous. *Cicadidae*.
- BB. Ocelli only two in number or wanting; males without musical organs.
- C. Antennae inserted in front of and between the eyes.
- D. Prothorax not prolonged above the abdomen.
- E. Hind tibiae armed with one or two stout teeth, and the tip crowned with short stout spines *Cercopidae*.

- DD. Prothorax prolonged into a horn or point above the abdomen *Membracidae*.
- AA. Beak apparently arising from between the front legs, or absent; tarsi one or two jointed; antennae usually prominent and thread like, sometimes wanting.
- B. Tarsi usually two-jointed; wings when present four in number.
- C. Wings transparent.
- D. Hind legs fitted for leaping; antennae nine or ten jointed. *Psyllidae*.
- DD. Legs long and slender, not fitted for leaping; antennae three to seven jointed. *Aphididae*.
- BB. Tarsi one-jointed; adult male without any beak, and with only two wings; female wingless, with the body either scale-like or gall-like in form, or grublike and clothed with wax. The waxy covering may be in the form of powder, of large tufts or plates, of a continuous layer, or of a thin scale beneath which the insect lives. *Coccidae*.

THE BEETLE

Harpalus caliginosus

GENERAL FEATURES.—How does the covering of this animal differ from that of the insects previously studied? Can you find the three divisions of the body from the dorsal side? From the ventral? Do you think this animal is fitted for the life it leads? In what ways? Draw longitudinal and lateral axes.

THE HEAD.—(1) Look on the dorsal side of the head for *eyes*. How many? What kind? Is there any significance in their position? On the dorsal side find also the *labrum* and the tips of the *mandibles*. How do the *mandibles* compare with the mandibles of other insects.

(2) Examine the ventral side of the head. Beginning with the lower surface find the *labial palpi* and the *tongue*, or *glossa*, situated in the central depression of the large, hard, mentum. On either side of the tongue find a pair of fleshy *paraglossae*, generally lighter in color than the mentum. Insert the scalpel in front of the paraglossae, loosen the labium, and with the tweezers carefully inserted, grasp it firmly and remove the parts studied. Lay them aside for further study. On either side of the mentum find the bases of the *antennae*. Notice their attachment to the head. Remove them and place them in proper relation by the side of the labrum.

The mouth parts next exposed are the *maxillae*. Remove them and look carefully for the three parts; the *lacinia*, *galea*, and *palpus*. Place them above the other parts. Remove next the mandibles and labrum and place them in proper position in front of the others. Draw all the mouth parts ($\times 4$).

Below the *mentum* is the enlarged gula divided into two parts by a line. How does it compare with that of a grasshopper?

THE THORAX.—(1) Observe the *prothorax* on both dorsal and ventral sides. Note its shape in front and back, its margins, and its size compared with the prothorax of other insects studied. On the ventral side observe the first pair of legs. Where are they attached? Are all the segments common to the legs present? Do you find the coxal cavity?

(2) Do you find the *mesothorax* and the *metathorax* on the ventral side? Trace the boundaries of the thorax and see if you find any peculiarities not common to insects.

Are the second and third pairs of legs attached to the thorax? How many segments in each? Notice the shape of the coxa and the coxal cavity in the second and third pairs of legs. Notice the position of the trochanter in the third pair of legs. Do you see any advantage in having it in this position?

Count the joints of the tarsus in each of the three pairs of legs. This characteristic is used in the classification of beetles.

Make a drawing of the ventral side of the thorax ($\times 4$).

(3) Lift up the outer wings on the dorsal side and pull them out at right angles to the body. These are the *elytra*. Notice from what segment of the thorax they come. To what in the butterfly and moth can they be compared? Do you think they could be used in flying? Do you know of any use to which they could be put? Do you find veins present? Do you find a line of division between the mesothorax and the metathorax? Look just under the elytra, above the inner wing, for a *degenerated appendage*. What segment of the thorax does it come from? What does it signify? This appendage is shown more plainly in the water beetle (*Dyticus*).

Study the inner wings as they lie folded over the abdomen. Can you make out the method of folding?

Straighten out the inner wing of the left side, being careful not to tear it while the tangle is being unrolled. Pin it down and look carefully at the wings. How do they compare in texture with the wings of other insects? Note the veins. Can you find the same veins and the same areas that are present in the wings of the grasshopper? Draw inner wing ($\times 4$).

(4) On the side of the abdomen now exposed look for lines of separation into segments. How many segments are there? Near the outer margin between the segments find the *spiracles*. Look at them closely and make out their shape and structure. Draw dorsal view of the animal as now exposed ($\times 2$).

DEVELOPMENT.—The eggs of the *Harpalus* are laid in protected places under boards and the larva, like the imago, is carnivorous. It has strong jaws and three pairs of jointed legs and is called a *grub*. From the larva it passes into the pupa state, from which it afterwards emerges an adult beetle.

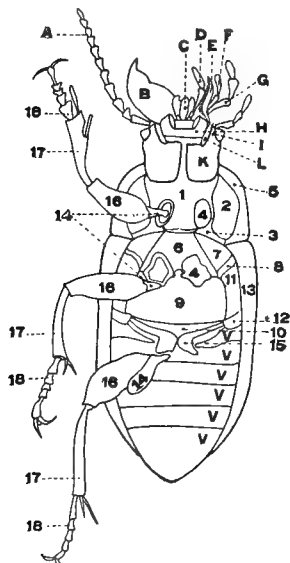
HABITS.—From the structure of this animal's mouth parts, what kind of food would it relish? Where is it found most abundantly? Is it beneficial or injurious? Study the living specimen. Note its excited motions in captivity. Can you tell why? Estimate its strength by tying it by the third leg to test its power of pulling, and also by putting a weight on its back.

CLASSIFICATION.—The *Harpalus caliginosus* belongs to the order *Coleoptera* and to the family *Carabidae*. The family contains many common beetles, some of which you have probably collected already. What other families of beetles have you represented in your collection? What is the meaning of the term *coleoptera*? How does it apply to this order?

Watch the *Harpalus* under the electric lights to find its habits of food getting. Does it fly? Try to make one fly. Some beetles of this family have no inner wings, and the outer ones have grown together. Can you tell why? Could their habits produce this effect?

CLASSIFICATION.—The student will find the collecting of beetles exceedingly interesting on account of their great variety, and diversity of external appearance. They may be traced to their families by the following table, but the help of a specialist will generally have to be secured in finding the genera and species.

Under surface of *Harpalus caliginosus* illustrating the parts most used in the classification which follows (after *Le Conte* and *Horn*).



- A. Antenna.
- B. Mandible.
- C. Ligula.
- D. Labial palpus.
- E. Maxilla inner lobe.
- F. Outer lobe.
- G. Maxillary palpus.
- H. Mentum.
- I. Genae.
- K. Gula, with the gular sutures.
- L. Buccal fissure.
- V. Ventral segments.

- 1. Prosternum.
- 2. Prosternal episternum.
- 3. Prosternal epimerum.
- 4. Coxal cavity, closed behind.
- 5. Inflexed side of pronotum.
- 6. Mesosternum.
- 7. Mesosternal episternum.
- 8. Mesosternal epimerum.
- 9. Metasternum.
- 10. Antecoxal piece.
- 11. Metasternal episternum.
- 12. Metasternal epimerum.
- 13. Inflexed side of elytrum.
- 14. Trochanters.
- 15. Posterior coxae.
- 16. Femora.
- 17. Tibiae.
- 18. Tarsi.

Table for Determining the More Common Families of the Coleoptera.

ADAPTED FROM COMSTOCK.

- A. Head not prolonged into a narrow beak; palpi always flexible; two gular sutures at least before and behind; prosternal sutures distinct; the epimera of the prothorax not meeting on the middle line behind the prosternum.....*Typical Coleoptera.*
- B. Hind tarsi with at least as many segments as the others.
- C. Tarsi usually apparently four-jointed, the fourth segment being reduced in size so as to form an indistinct segment at the base of the last segment, with which it is immovably united; the first three segments of the tarsi dilated and brush-like beneath; the third segment bilobed. In a single family, the Spondylidae, the fourth segment of the tarsus, although much reduced and immovably united with the fifth, is distinctly visible, the first three segments are but slightly dilated, and the third is either bilobed or not.....*Phytophaga.*
- D. Fourth segment of tarsus distinctly visible; segments of antennae with deep impressions containing the organs of special sense.....*Spondylidae.*
- DD. Fourth segment of tarsus inconspicuous; organs of special sense of antennae diffused. This group contains three families, which are so connected by intermediate forms that it is not easy to separate them. The following characters will aid the student in separating the more typical forms:
 - E. Body elongate; antennae almost always long, often as long as the body or longer. The larvae are borers.
Cerambycidae.
 - EE. Body short and more or less oval; antennae short.
 - F. Front not prolonged into a beak; usually the tip of the abdomen is covered by the elytra. Both larvae and adults feed on the leaves of plants.....*Chrysomelidae.*
- CC. Tarsi varying in form, but when five-jointed not of the type described under C, the joint between the fourth and fifth segments being flexible.
- D. Ventral part of the first segment of the abdomen divided by the hind coxal cavities, so that the sides are separated from the very small medial part.

- E. Metasternum with an antecoxal piece, separated by a well-marked suture reaching from one side to the other, and extending in a triangular process between the hind coxae.
- F. Antennae eleven-jointed; hind coxae mobile, and of the usual form; habits terrestrial.
- G. Antennae inserted on the front above the base of the mandibles *Cicindelidae*.
- GG. Antennae arising at the side of the head between the base of the mandibles and the eyes. . . . *Carabidae*.
- EE. Metasternum either with a very short antecoxal piece, which is separated by an indistinct suture, and which is not prolonged posteriorly between the coxae, or without an antecoxal piece.
- F. Metasternum with a very short antecoxal piece.
Amphizoidae.
- FF. Metasternum without an antecoxal piece.
- G. Legs fitted for swimming.
- H. With only two eyes. *Dytiscidae*.
- HH. With four eyes, two above and two below.
Gyrinidae.
- GG. Legs fitted for walking. *Rhyssodidae*.
- DD. Ventral part of the first segment of the abdomen visible for its entire breadth.
- E. Antennae with a lamellate club.
- F. Plates composing club of antennae not capable of close apposition, and usually not flattened. . . *Lucanidae*.
- FF. Plates composing club of antennae capable of close apposition, and flattened. *Scarabaeidae*.
- EE. Antennae either clubbed or not, but when clubbed not lamellate.
- F. Elytra short, leaving the greater part of the abdomen exposed; the suture between the elytra when closed straight; wings present, and when not in use folded beneath the short elytra; the dorsal part of the abdominal segments entirely horny.

- G. Abdomen flexible, and with seven or eight segments visible below.....*Staphylinidae*.
- FF. Elytra usually long, covering the greater part of the abdomen; when short the wings are wanting, or if present are not folded under the short elytra when at rest; the dorsal part of the abdominal segments partly membranous.
- G. Hind tarsi five-jointed.
- H. Antennae elbowed, and clavate.
- I. Elytra truncate behind, leaving two segments of the abdomen uncovered.....*Histeridae*.
- HH. Antennae rarely elbowed, and then not clavate.
- I. Maxillary palpi as long as or longer than the antennae *Hydrophilidae*.
- II. Maxillary palpi much shorter than the antennae.
- J. Tarsal claws of usual size; ventral abdominal segments usually free; sometimes (*Buprestidae*) the first two are grown together.
- K. Abdomen with only five ventral segments.
- L. Femur joined to the side of the trochanter.
- M. Anterior coxae globular or transverse, usually projecting but little from the coxal cavity.
- N. Anterior coxae globular.
- O. Prosternum with a process which extends backward into a groove in the mesosternum.
- P. The first two abdominal segments grown together on the ventral side:
Buprestidae.
- PP. Ventral segments free.
- Q. Prothorax loosely joined to the mesothorax; front coxal cavities entirely in the prosternum.
Elateridae.
- OO. Prosternum without a process

ARTHROPODS

received by the mesosternum, although it may be prolonged so as to meet the mesosternum.

P. Posterior coxae separated.

Q. Body very depressed; middle cavities not closed externally by a meeting of the mesosternum and metasternum .. *Cucujidae*.

MM. Anterior coxae conical, and projecting prominently from the coxal cavities.

N. Posterior coxae dilated into plates partially protecting the femora, at least at their bases.

O. Antennae with the last three segments forming a large club.

Dermestidae.

KK. Abdomen with six or more ventral segments,

L. Anterior coxae either globular or conical.

M. Anterior coxae globular.

N. Prosternum prolonged behind, forming an acute process moving in the mesosternum *Elateridae*.

NN. Prosternum not prolonged behind.

.. *Leptinidae*.

MM. Anterior coxae conical.

N. Posterior coxae more or less conical and prominent, at least internally, not covered by the femora in repose.

O. Posterior coxae widely separated.

P. Eyes wanting or inconspicuous.

Silphidae.

OO. Posterior coxae approximate.

P. Antennae gradually thickened, or clavate; posterior tarsi not widened *Silphidae*.

PP. Antennae setaceous, filiform, serrate, pectinate, or flabellate, rarely with three somewhat larger terminal segments, in which case the tarsi are widened.

Q. Anterior coxae long, with distinct trochantins.

R. Abdomen with seven or eight ventral segments

Lampyridae.

GG. Hind tarsi either only three-jointed or four-jointed, but apparently three-jointed, the third segment being small and concealed in a notch at the end of the second segment. (See also GGG.)

H. Wings not fringed with hairs.

I. Tarsi with second segment dilated.

J. Tarsal claws appendiculate or toothed; first ventral abdominal segment with distinct curved coxal lines.....*Coccinellidae.*

GGG. All tarsi four-jointed.

H. The first four abdominal segments grown together on the ventral side.

I. Tibiae not dilated nor fitted for digging.

Colydiidae.

HH. Ventral segments of abdomen not grown together.

I. Wings fringed with hairs.

J. Hind coxae contiguous and with plates covering the femora entirely or in part. *Silphidae.*

BB. Hind tarsi with only four segments, the fore tarsi, and almost always the middle tarsi also, with five segments.

C. Anterior coxal cavities closed behind.

D. Tarsal claws simple.

E. Abdomen with five ventral segments.

F. Ventral abdominal segments in part grown together.

GG. Penultimate segment of tarsi not spongy.

Tenebrionidae.

- EE. Abdomen with six ventral segments.
 - F. Ventral abdominal segments free.....*Silphidae*.
 - DD. Tarsal claws pectinate.....*Cistelidae*.
 - CC. Anterior coxal cavities open behind.
 - D. Head not strongly and suddenly constricted at base.
 - E. Middle coxae not very prominent.
 - F. Antennae free.
 - G. Prothorax margined at the sides.
 - H. Epimera of mesothorax reaching the coxae.
 - I. Metasternum long; epimera of metathorax visible*Melandryidae*.
 - II. Metasternum quadrate; epimera of metathorax covered*Cucujidae*.
 - DD. Head strongly constricted at base.
 - E. Head suddenly narrowed behind.
 - F. Prothorax with the side pieces not separated from the pronotum by a suture.
 - G. Tarsi perfect with distinct claws; eyes normal.
 - H. Prothorax at base narrower than the elytra.
 - I. Hind coxae large, prominent.
 - J. Claws cleft or toothed; front vertical.
 - Meloidae*.
 - HH. Prothorax, at base, as wide as the elytra.
 - Rhipiphoridae*.
 - FF. Lateral suture of prothorax distinct; base of prothorax as wide as the elytra.
 - G. Antennae filiform.
 - H. Hind coxae platelike.....*Mordellidae*.
 - HH. Hind coxae not platelike.....*Melandryidae*.
- AA. Head more or less prolonged into a beak; palpi short and rigid; gular sutures confluent on the median line; prosternal sutures wanting; the epimera of the prothorax meeting on the middle line behind the prosternum.....*Rynchophora*.
- B. Elytra with no fold or with a very feeble one on the lower surface near the outer edge; pygidium of male and female alike.
 - C. Labrum distinct.....*Rhinomaccridae*.
- CC. Labrum wanting.

D. Mandibles flat, toothed on inner and outer sides.

Rhynchitidae.

DD. Mandibles stout, pincer-shaped.....*Attelabidae.*

BB. Elytra with a very strong fold on the lower surface near the outer margin.

C. The last dorsal segment (pygidium) of the male divided transversely, so that this sex appears to have one more dorsal segment than the female.

D. Antennae with a ringed or solid club.

EE. Tarsi usually dilated, brushlike beneath.

F. Mandibles with a deciduous piece, which is lost soon after emergence from the pupa state, and leaves a scar.

Otiorhynchidae.

FF. Mandibles without accessory piece in the pupa state, and therefore without a scar in the adult state.

Curculionidae.

CC. Pygidium of both sexes undivided.

D. Pygidium horizontal; tibiae usually serrate....*Scolytidae.*

DD. Pygidium vertical or declivous; tibiae not serrate.

E. Antennae geniculate; labrum wanting; last spiracle covered by ventral segments.....*Calandridae.*

THE HONEY BEE

Apis mellifica

GENERAL FEATURES.—(1) The general characteristics of the bee are the same as those of the other insects studied, but there are certain specializations of structure that make it a very peculiar animal.

(2) Observe the covering of the entire animal. Note the manner in which the thorax and abdomen are joined. Is it like the grasshopper in this? Is it the thorax or the abdomen that is modified? Such a structure is called a *pedicel*.

THE HEAD.—(1) Study the front part of the head. How many *ocelli*? How are they arranged? Note the *antennae*. Are they like those of the grasshopper? How many segments? Do you notice anything peculiar about the surface of the head?

(2) Find the following mouth parts:—a, A thin small flap, the *labrum*. Is it movable? b, A pair of strong jaws, or *mandibles*, hard and black at the tip. For what are these used? c, A *proboscis*, which will be found bent back under the mouth. Remove it with the tweezers, being careful not to injure any of the parts. Spread the parts out and find the central, long, hairy *tongue*, the short *labial palpi* close to the tongue, and the long, slender blades, the *maxillae*.

Get these in the right position on a slide, under a cover glass, and place under the low power of the microscope. Make the following drawings:

The front of the head ($\times 5$).

The proboscis ($\times 10$).

THE THORAX.—(1) Observe the enormous development of the thorax. Is such a thorax of special value to the bee?

(2) Study the bee in flight. How are the wings disposed when flying? When at rest? Are both pairs of wings used in flight? Look for a small wing cover in front of the fore wing. It is the *tegula*. To what in the beetle is it homologous? Study the method of attachment of the wings. Remove one of the front and one of the hind wings.

Are the wings separate, or fastened together?

Study the venation of the wings. Do you find the costal, median, and internal areas? Is the venation the same in both pairs of wings?

Draw both wings ($\times 4$).

(3) Lay the wings in their natural order on a glass slide. Examine the internal margin of the outer, or front wing, and the costal margin of the inner, or hind wing. Do you find there a method of attachment of the wings to one another? Can you tell now how the wings are used? These hooks are called *hamuli*. Make a drawing of these margins showing how they are specialized.

(4) Examine the attachment of the legs to the body. Are all the segments present? Are all the legs alike. What specializations do you notice in the second and third pairs? One joint of the tarsus and one of the tibia are enlarged. This flattened portion is called the *pollen basket*. The pollen basket is formed by an enlargement and curving of two of the segments of the leg. Which segments are they? Have you ever seen a bee carrying pollen? How is the pollen fastened to the leg? Does each leg have a pollen basket?

Draw one of the third pair of legs ($\times 3$).

THE ABDOMEN.—(1) How many segments in the abdomen of the bee? Is the number the same on the dorsal and ventral sides?

(2) Find the *sting* by laying the bee on the dorsal side and pressing on the abdomen about four segments from the posterior end. The sting will appear between the segments. Seize the tip firmly with the tweezers and pull it out with a quick movement. Lay the sting and the parts that come with it on a slide and with the needles arrange the parts carefully.

The large part back behind the sting contains the *poison glands* and the *sac* for holding the secreted poison. Look

for the ducts leading from the glands to the sac. With a needle attempt to pry apart the sides of the sting.

Draw sting and glands ($\times 4$).

Draw ventral side of the abdomen showing where the sting left it.

The sting of a working bee is an ovipositor similar to that of a grasshopper, specialized. The worker is therefore a female insect so modified that it has no sex, but is called a *neuter*. Of what use is this specialization to the animal?

DEVELOPMENT.—(1) The cells of the honeycomb are prepared by the neuter, or working bees, but the eggs are all laid by the queen, a large female bee which has an ovipositor. The eggs are placed in the bottom of the cell and are soon hatched into maggots which are fed continually by the workers.

(2) Like the larva of all insects, they eat voraciously and grow by molting until they are ready to pass into the pupa state. By this time the larva fills the cell nearly to the top and it spins a vestige of a cocoon just above its head. The working bees build a top across the cell and the pupa awaits its final change.

(3) After a time varying in length according to the weather, the change from a footless larva to a highly organized imago is completed and the animal bursts through both coverings and is a full grown bee. Is this complete or incomplete metamorphosis? What does the spinning of the thin web by the insect indicate?

Bees and similar insects belong to the order Hymenoptera. Is the name appropriate?

HABITS.—(1) Did you ever see a bee on a flower? The bumblebee on a clover blossom is a good one to watch.

What is it seeking as it goes from flower to flower?

On the little stamens inside the flower is found the pollen, or minute whitish seed powder, which readily falls out on being disturbed. It is necessary that this be removed from one flower to another in order that the pistil, or central stalk may have the pollen dust spread upon it. The bee gathers a little of this pollen, but a greater amount of it adheres to its hairy body, and as it goes from flower to flower some of the pollen is rubbed off and reaches the proper place on the pistil of the flower. But while the bee uses some of this pollen, its great object in visiting the flowers is to collect the sweet fluid, the nectar, which is secreted by the small glands at the base of the flower. By secreting this nectar at the base, the flower compels the bee to press open the parts of the flower and rub all the internal parts with its body, thus accomplishes the cross fertilization of the plants.

What specializations in the bee are peculiarly adapted to the structure of the flower?

(2) In a colony of bees there are three kinds of insects, females, or queens, males, or drones, and neuters which are females with ovipositor specialized into a sting, or aborted as in the ants.

In the hive of the honeybee the larvae are all alike at first, but after awhile the workers feed some of the larvæ on one kind of food and some on another. This develops them into different kinds, such as queens, drones or workers. It seems that the kind of food given the larva determines the sex and form of the animal.

(3) Many Hymenoptera build some kind of a home and take some care of the young. In the family Apidae, bees, the cells are generally built from a waxy substance excreted

between the segments of the abdomen. In some of the cells young are reared, in some, beebread is stored, and in others, honey.

The honey is stored for use during inactive periods. When are these periods? Does the honeybee eat during the winter, or does it hibernate?

In the family Vespidae, wasps, the cells are made out of lint obtained from weather-worn houses or wood. These rear their young as in the preceding family, but do not make honey or store food. They hibernate during winter. Where do they stay?

In the family Formicidae, ants, the dwelling is generally made by burrowing under ground and, in many species this is carried on until the burrow is large and complex. When these burrows are attacked by an enemy that is likely to destroy them, the ants carry the young to a safe place. During the summer most species of ants store away food for use during periods of inactivity.

Other families have other methods of building or of keeping food. Can you tell the habits of the mud wasp?

(4) In some families of the Hymenoptera specialization of structure has gone so far that it has resulted in a kind of self-regulating political economy. By reason of their structure certain tasks are imposed on some animals and other tasks on others. However, they all partake of the common store and are entitled to many of the privileges resulting from the aggregate of their labor.

It takes a whole colony of bees or ants to perform the work necessary to the life of one individual; and the entire community working together, with common interests and in perfect harmony represents a higher state of intelligence

than is found in other insects. Compare this plan with human industry and government. Industries and government make civilization and civilization indicates the common intelligence of mankind.

CLASSIFICATION.—From A. E. POPENOE.—The bees are very difficult to trace to the species. The following table will be found convenient.

Table of Principal Families of the Hymenoptera.

SECTION I. Stingers. Females provided with a sting, modified ovipositor.

Apidae. Honeybees, bumblebees, etc.

Bodies hairy, stout, abdomen sessile; wings not folded in repose; prothorax a narrow collar; mandibles of usual shape; but labium, tongue and maxillae long, slender and used as a haustellum; hind tibiae and first tarsal joint broad and concave in most species, used as a pollen basket; legs of moderate length.

Vespidæ. Hornets, wasps, etc.

Bodies more slender, smooth, firm; abdomen sessile; wings (at least fore ones) folded lengthwise in repose; prothorax extending back on sides to base of anterior wings; antennae more or less clavate, elbowed; legs moderate.

Crabronidae. Sand wasps.

Bodies firm, moderately slender, strongly punctured, slightly hairy; head large squarish; antennae elbowed, the long second joint received when at rest in a vertical frontal groove; fore feet adapted for digging, broad, spiny; legs of moderate length.

Bembecidae. Horse guards.

Bodies somewhat flattened, stout, rather smooth; head large; labrum long, triangular; feet stout, for digging, but of moderate length. Large black and yellow insects, feeding on flies, which they seize about animals or along roads.

Sphegidae. Mud wasps.

Bodies rather long and slender; prothorax prolonged into a neck in front; abdomen petiolated; legs long, spiny; mandibles long, curved, sharp; antennae long and filiform.

Pompilidae.

Bodies rather long and slender; prothorax prolonged backward to base of wings; wings large and broad; legs long and spiny, slender; antennae long and filiform, not elbowed, usually coiled; colors chiefly velvety black or indigo blue, often with red spots; wings opaque, black, blue or yellow.

Mutillidae. Stinging ants, cow killers.

Males winged, females apterous; bodies hairy, black, red or yellow, spotted or banded; ocelli generally absent; females found running along hot roads or paths; males found about sunflowers, etc.

Formicidae. Ants.

Males and females winged at maturity; neuters wingless; bodies rather smooth, slender; colors usually red, yellow or brownish black, rather shining. Living in colonies in all situations; females largest, males and neuters smaller.

SECTION 2. Piercers. Provided with an unmodified ovipositor, or at least without poison glands.

Chrysididae. Cuckoo flies (parasitic).

Ocelli present; antennae thirteen-jointed, elbowed; maxillary palpi five-jointed, labial, three-jointed; ovipositor stinglike, long-jointed, but no poison gland; abdomen ventrally somewhat hollowed out; body firm, coarsely punctured; colors usually shining green or black.

Ichneumonidae. Ichneumon parasites.

Bodies long, slender; ovipositor long, usually exerted; antennae long, slender, filiform, many jointed, not elbowed; internal parasites on other insects, very beneficial.

Proctotrypidae. Egg parasites.

Bodies very small, slender; antennae usually long and slender;

wings nearly without veins, covered with minute hairs; highly beneficial insects, living in the eggs of other insects.

Chalcididae. Chalcis flies.

Small, generally polished, metallic; hind thighs frequently thickened; antennae six to fourteen jointed, elbowed; wings often with but few veins; beneficial, parasitic.

Cynipidae. Gall flies.

Small; abdomen compressed, short, second or second and third segments much broader than the remaining; a long, slender ovipositor lying concealed in a ventral groove; antennae straight, thirteen to sixteen-jointed.

Tenthredinidae. Saw flies.

Head, thorax and abdomen less markedly distinct than in other Hymenoptera; wings large and broad, many cross veins; antennae straight, filiform, clavate or pectinate; ovipositor saw like; larvae caterpillarlike, living on leaves, and known as slugs.

Uroceridae. Horntails.

Bodies cylindrical with parallel sides, long; antennae long, filiform, rather stout; ovipositor stout, exerted, attached to middle of abdomen, and extending beyond the tip of body; larvae very destructive wood borers.

THE HOUSE FLY

Musca domestica

GENERAL CHARACTERISTICS.—Notice the method of union of the head with the thorax and the thorax with the abdomen. Observe the covering of the body. Of what use is the hair? Note the markings of the body. How many segments in the abdomen? Do you find an ovipositor?

THE HEAD.—(1) Note the large surface covered by the eyes. Do you find simple eyes? Remove the head, plac-

ing it on a slide, and put it under the lens of the dissecting microscope or the low power of the microscope without a cover glass. Look for the *antennae*. When you find them remove one with a scalpel and tweezers.

Make a drawing of the head as it appears from the front.

Draw one of the antennæ. Draw longitudinal and lateral axes.

(2) Find the tongue bent back under the head. Straighten it out and examine the joint. Seize it carefully with the tweezers, and pull it out. Put it on a slide properly spread out and put over it a cover glass. Examine under low power. Note the shape, markings and structure.

Find the following parts:

a. The main shaft, the *tongue*, is divided into two spreading parts, the labial palpi, at the end. Do you find the parts smooth or rough? Is there a system of projections? What is their arrangement? These are *tracheal tubes* and serve to keep the tongue well spread.

b. On the head near the base of the tongue find two slender projections, the *mandibles*, which are small in this species and almost undeveloped in the male, but are very prominent in the females of the mosquitoes and horseflies.

c. The jointed, hairy, maxillary palpi on the shaft of the tongue.

Draw proboscis of fly enlarged.

THE THORAX.—(1) How many pairs of legs? Where attached to the body? How many fully developed wings? Behind the wings is a pair of membranes, the *alulets*. Are these attached to the wings or are they separate?

(2) Under the alulets are a pair of small white appendages ending in a knob. Where are they attached to the

body? Do you know of any use to which they may be put by the fly? They are called *balancers*. What organ in the other insects do they take the place of?

Make a drawing of the wing ($\times 4$).

Remove the balancer, put it under low power of microscope, and draw.

(3) Remove one of the legs from the body. How many segments? Remove the tarsus and put it under the low power of the microscope. Note the two hooks and the pads. Study the structure closely. The pads are called *pulvilli* and are used to secrete a sticky fluid by means of which the fly adheres to smooth surfaces or to the ceiling.

Draw the tarsus.

Draw dorsal view of fly ($\times 2$).

The fly belongs to the order *Diptera*, a group of insects having two wings.

DEVELOPMENT.—(1) The eggs of the fly are laid in decaying waste matter and after a short time the larva, a headless, footless maggot is hatched. Like other larvæ it eats ravenously for a few days, molts several times, and finally assumes a tough brown covering which is the *crysalis* of the pupa state.

After remaining about a week in the pupa state it emerges as a full grown *imago*.

(2) It is an easy matter to raise house flies and watch their metamorphosis.

Draw larva and pupa ($\times 4$).

HABITS.—Flies are scavengers and are therefore of the greatest benefit in the economy of nature. Why is this? It is also suspected that flies carry and distribute the germs of typhoid fever, and that mosquitoes carry and distribute

malarial fevers. What time of the year are they most abundant? Why? What effect does cleanliness have on the number of flies and mosquitoes? How do they spend the winter? How do they defend themselves?

What are the habits of the mosquito, the horse fly and the botfly?

CLASSIFICATION.—From A. E. POPENOE.—By this table flies can be traced to their families; for further identification consult a specialist.

Table of the Principal Families of Diptera.

SECTION 1. *Nemocera*. Antennæ of more than six joints; palpi four or five-jointed.

Culicidae. Mosquitoes.

Ocelli none; thorax without transverse suture; costal vein continued around the margin of the wing, fringed with scales; larvae and pupae aquatic.

Tipulidae. Crane flies.

Ocelli none—except in one genus; thorax with a V-shaped transverse suture; legs very elongated; haustellum short, terminated by two large, fleshy lips; palpi longer than proboscis; four-jointed.

SECTION 2. *Brachycera*. Antennæ short, not having apparently more than three distinct joints; palpi one or two-jointed.

Stratiomyidae.

Third joint of antennae annulated, sometimes divided into several portions; tibiae without spurs. Costal vein reaching only to middle of wing; three basal cells much prolonged.

Tabanidae. Breeze flies, horseflies.

Third joint of antennae annulated, rarely divided into distinct joints, always without style or bristle; haustellum of the male with

four, or the female with six, bristles; marginal vein running round the whole border of the wing; tegulae rather large.

Asilidae. Soldier flies.

Third joint of antennae simple; under lip forming a horny sheath about as long as head; body long, clothed with stiff bristles; thorax narrowed before; face bearded below; predaceous.

Bombyliidae. Bee flies.

Third joint of antennae simple; body short and thick; wings extended horizontally on each side of body; proboscis long, projected in front of head; ocelli three; legs long and slender; body generally thickly clothed with hairs, which are easily rubbed off.

Syrphidae. Syrphus flies.

Proboscis with four internal pieces, long, elbowed near the base, terminated by two large labial lobes; antennae three-jointed, last joint largest, dilated, simple, bearing a bristle. Insects of moderate or large size, variegated in color.

Dolichopidae.

Antennae short, third joint oval, or palette-shaped, emitting a long seta, or bristle; legs long and slender, strongly bristled. Small, slender flies, generally of brilliant metallic colors; found on leaves and in damp places.

Oestridae. Gadflies, botflies.

Antennae short, inserted in rounded pits; middle part of face very narrow; mouth very small, organs rudimentary; tegulae large; bodies rather large to quite large, hairy.

Tachinidae. Tachina flies.

Bristle of antennae bare, or with very short pubescence; thorax short; body bristly, stout; abdomen oval or cylindric, first segment much shortened; many of the gray species with tip of abdomen reddish.

Muscidae. House flies, blowflies.

Antennal bristle entirely plumose, or pectinate; body not slender;

thorax short; proboscis short, thick, generally retractile; small or medium insects; larvae, maggots, usually scavengers.

Ortalidae. Gallflies.

Abdomen pointed; wings generally spotted or banded; front prominent; mouth wide; proboscis thick; larvae bore in stems of herbs.

Hippoboscidae. Sheep ticks.

Head flattened, sunken thorax; wingless, degraded, parasitic forms.

THE DRAGON FLY

Libellula sp.

GENERAL CHARACTERISTICS.—What is the most striking difference between this insect and the others studied? How are the wings held? Is there an unusual freedom of the head? Of what value is it? Make a diagram showing the longitudinal and lateral axes.

THE HEAD.—How much of the head is devoted to the eyes? The eyes of some species of dragon fly are thought to have as many as twelve thousand five hundred *facets* in each eye. Are *ocelli* present? Do you find *antennae*? What accounts for the condition in which you find the antennæ?

Draw front of head ($\times 2$).

Beginning with the labrum find all the mouth parts as in the grasshopper, and remove them with forceps.

Draw mouth parts ($\times 4$).

THE THORAX.—(1) Study the attachment of the legs to the body. How many *segments* in the legs? Of what use are the legs of a dragon fly?

(2) Observe the peculiar color and venation of the wings. How do they differ from the wings of a bee and a house fly? Examine the attachment of the wings to the body. What motions have they?

How do you account for the large thorax of the dragon fly?

Draw one wing showing venation ($\times 3$).

Draw entire dorsal view of dragon fly ($\times 1$).

ABDOMEN.—Count the number of segments and observe the attachment of the abdomen to the thorax.

How many spiracles do you find? On what segments?

The dragon fly belongs to the order Neuroptera. Is the name appropriate?

DEVELOPMENT.—(1) The eggs are deposited in water where they are soon hatched into *nymphs* which crawl along the bottom of the water. The nymph is carnivorous and very voracious, consequently it grows rapidly and molts often. Before molting the last time it crawls out of the water and fastening itself to some convenient projecting place and breaking the shell along the dorsal side, it comes out of its shell into a new world of light and air which contrasts strangely with its former abode in darkness and filthy water.

(2) Nymphs may be easily obtained by dredging ponds with a net. Get a few and put them in jars filled with water. Feed them on insects and small crustaceans obtained by dredging the ponds.

(3) Study the nymph carefully. Do you find three divisions of the body?

How does each part differ from the corresponding part in the adult?

Note the general shape of the *head*, the large *eyes*, prominent *jaws* and large *labrum*. The most peculiar thing is the enormous development of the lower lip, or labium. Open it with the needle and note its structure. What use can the animal have for such an organ.? Do you think such a structure would help in gathering food? Why? Watch a live specimen gathering food. This can be better noted after putting in fresh dredging from the pond.

Draw front view of head ($\times 4$).

(4) Note the legs. How and where are they attached? Compare them with the legs of the adult.

Observe the rudimentary wings. Are there two pairs? To what are they attached?

(5) Count the segments of the abdomen. Do you find *spiracles* along the sides? Since the nymph lives in water it breathes air from the water instead of from the atmosphere as in the adult. The water is taken in at the anal opening, carried over *tracheal gills*, and after purifying the blood, is expelled again at the same opening. Study this method of respiration. Find and draw gills.

Draw nymph ($\times 2$).

(6) Get a number of specimens of different sizes illustrating different stages of growth and make a series of drawings showing the development of the dragon fly.

HABITS.—Watch the dragon fly in motion. Why has it such a jerky, uncertain motion? Does it seem to have the power of going in a definite direction? What is its food? How does it obtain it? Why is it called mosquito hawk? Why does it spend so much time near water? How does the dragon fly spend the winter? At what time in the spring does it appear? Is the development complete or in-

complete? Can you think of a plausible reason for calling it a dragon fly?

CLASSIFICATION.—From A. E. POPENOE.

Table of Principal Families of Neuroptera.

- A. Four or two distinct wings.
 - B. Antennae inconspicuous, subulate, short and slender.
 - C. Fore and hind wings nearly of same length; tarsi three-jointedDragon flies, *Libellulidae*.
 - CC. Hind wings either smaller or wanting; tarsi four or five-jointedDay flies, *Ephemeridae*.
 - BB. Antennae usually inconspicuous; setiform, filiform, clavate, capitate, or pectinate.
 - D. Tarsi two or three-jointed; wings unequal.
 - E. Hind wings smaller.....Bookmites, *Psocidae*.
 - EE. Hind wings of same size or broader than fore wings.
 - Perlidae*.
 - DD. Tarsi four-jointed; wings unequal.
 - White ants, *Termitidae*.
 - DDD. Tarsi five—sometimes apparently but four—jointed.
 - F. Hind wings with no anal space, not folded.
 - G. Mouth more or less rostrated.....*Panorpidae*.
 - GG. Mouth not rostrate.....*Hemerobidae*.
 - FF. Hind wings with a folded anal space.
 - H. Wings reticulate*Sialidae*.
 - HH. Transverse veins rather few.....*Phryganidae*.
 - AA. Wings rudimentary or wanting.
 - B. Mouth rostrate*Panorpidae*.
 - BB. Mouth not rostrate.
 - C. Tarsi five-jointed.
 - CC. Tarsi four-jointed*Phryganidae*.
 - CCC. Tarsi three-jointed*Termitidae*.
 - D. Wings absent; or two, rudimentary, leathery....*Psocidae*.
 - DD. Four rudimentary wings, veins visible.....*Perlidae*.

NOTE.—According to recent classifications the order Neuroptera is divided into several groups each of which is an order. The Drag-

on Fly belongs to the Order Odonata according to Comstock and contains but one family, i. e., Libellulidae. The classification here given is convenient and contains a number of families which would not otherwise be included.

SUMMARY OF INSECTS STUDIED.

Write answers to the following questions in clear definite statements :

(1) How are insects covered? How many divisions to the body?

(2) How many mouth parts, when fully developed? What are they?

(3) How do insects see? Feel? Hear? Taste? Do they smell?

(4) How is locomotion accomplished?

(5) What is the breathing process?

(6) What is the method of digesting food?

(7) How is the blood circulated through the body?

(8) What is the plan of the nervous system?

(9) How are insects reproduced? Through what stages do they pass?

(10) How are their characteristics grouped for classification?

(11) Make a list of similarities and differences in a diagrammatic form as in the study of Orthoptera, and in the list of differences put in the entire number of insects studied, letting each order be represented by one insect.

This will give the class and order definitions of insects.

CLASSIFICATION.—Just as we collected the different grasshoppers into the family Acrididæ, and the grasshopper, cricket, cockroach, and locust into the order Orthoptera, so now we group all the animals we have studied into the *class* insecta. As a representative of the family the grasshopper has certain characteristics; as a representative of the order, certain other characteristics; and as a member of a class, the grasshopper and the others just studied have the structures in common which have been outlined under the head of similarities.

But in the last comparison since the definition of the class was found by similarities and the definition of the order by the differences, we should find the differences now about the same as the likenesses when we made our first comparison. Find if this is true.

How could we get similarities for the orders Coleoptera, Hymenoptera and Lepidoptera that would be the same as the differences we have found?

THE SOCIAL LIFE OF INSECTS.—It has been noticed how perfectly each animal is fitted for the sphere of life in which it moves. Whatever it does it seems to be especially fitted for doing. Thus the entire structure is specialized, some of the organs in one direction and some in another; but whatever may be the shape or texture of the organ, it helps the animal to live in the surroundings in which it is placed.

The difficulties of these surroundings are many and cause every year the death of millions of insects, so that if some provision were not made in the structure of the animal to enable it to battle against these adverse circumstances the entire class would become extinct. It is really then a battle against death which the insects wage and their specialized

organs are their weapons of defense. The following are some of the things against which they continually struggle:

(1) ENEMIES.—Every insect is surrounded by myriads of hungry aggressive foes which it must combat or elude if it lives.

To do this some animals have modified mouth parts for fighting; others, hard shells; others, wings for sudden and rapid flight; others, legs developed for leaping; others, glands for emitting an offensive odor; others, a sting; others adopt the color of some article, as leaf, bark or stone, which is not food for their enemies; others imitate the color of an animal which is not relished by their enemies; others burrow into the ground; while many have compound eyes, by means of which they detect the approach of an enemy in time to escape. This vigilance applies in some cases not to the insects themselves only, but is exercised toward the offspring, by placing the eggs in protected places, and by defending the young in all stages from attack.

(2) FOOD SUPPLY.—The food problem is an important one and every insect is well prepared to get some certain food in a certain way. Some have mouth parts for tearing or masticating dead or living prey; others, for sucking blood or sap; others, for getting nectar from flowers; others, for using the pollen of flowers; others, for biting or masticating the entire leaf; others, for boring into woody stems or roots and devouring them; others, for penetrating grain; others, for rasping and absorbing liquid; others for living on decayed vegetable matter, while some do not have mouth parts in the mature state and hence live without food until they die of starvation or accident.

In nearly all of these the food is obtained by the mouth

parts alone, but in some the front legs are used for seizing and holding the food, and in others the legs are used for transporting food. Usually the food is devoured where it is found, but in some cases it is stored, and occasionally it is stored for the young only.

(3) CLIMATE.—The rigors of the climate form a serious check to the success of insects, and to meet it they adopt the method best suited to their structure. The number of spiracles and the great air capacity of insects render it impossible for them to lead a normal life in cold weather. Therefore the problem with which they have to contend is how to maintain life when food is exhausted and when the temperature is too low for muscular activity.

All, or nearly all of the insects that live over winter in the adult state are for a greater or less length of time in a dormant state, *i. e.*, a state in which they eat nothing, and breathing as well as circulation of blood is almost stopped. This is called *hibernation*, and the animal is said to *hibernate*.

In addition to hibernation some of them build houses, and store food for use when food is scarce, others go deep into the ground on the approach of winter, others seek protection in decayed logs and under bark, others in straw or corn husks, while others scarcely attempting to seek protection select any place partially hidden from view, and remain all winter or until they are frozen.

Many of the insects that do not hibernate as adults spend the winter in the pupa state, while others remain in the egg. The eggs and the pupæ are usually protected against inclement weather by being in the earth, in sheltered places or by having thick, warm cocoons. The placing of the eggs and weaving of the cocoons are accomplished by spe-

cialized organs. But in spite of all this care many insects perish every winter, and during severe winters nearly all of certain species are killed. To offset this annual slaughter and to prevent annihilation by the ceaseless struggle of the insect with his surroundings, the reproductive power of nearly all insects is extremely great. Unless checked by some agency almost any insect would multiply so rapidly that it would, in a short time, become a serious menace to the welfare of man.

If the winter season should become longer and colder, what would become of those animals that make little preparation for it? How could they prevent this result? If by circumstances an animal is driven into a region of longer or more severe winter what would be the result?

If the food supply of certain insects should become almost exhausted, how could they still survive?

If the enemies of a certain species of insect should become weaker or more powerful, would it affect the insect?

What effect will this struggle with environment have on the insect after it has gone on, generation after generation and year after year?

The larva of the honeybee which is snugly tucked away in a cell, and fed with every delicacy which it could wish, is covered over when it has finished growing by a soft, tough covering by the faithful workers. It would seem that this would be sufficient, but it is not, for the larva spins above its own head a weak, worthless fragment of a cocoon. Why does it do this? If the cell and cover were not there would it need this cocoon? If the cell were not there do you think it would build a better cocoon? Does this suggest anything of the past history of the bee?

Which do you think would specialize and change their parts more rapidly, the bee or the grasshopper? Why?

Would all species of the same genus change with the same rapidity? Would the same species all be alike? This produces what we call *varieties* in certain species.

For example, all dogs belong to the same species, but there is quite a difference between the Newfoundland and the Poodle. The different varieties of dogs have been produced by taking advantage of the natural differences of dogs and subjecting the animals to different surroundings which have developed different physical and mental traits.

In the same way insects of a certain species being already somewhat different, when subjected to varying conditions become different enough to be placed in different varieties and sometimes in different species.

Make lists in answer to the following questions:

- (1) What insects use the mouth parts for biting?
- (2) What insects use the mouth parts for sucking?
- (3) What insects use their legs for crawling or walking?
- (4) What insects use their legs for alighting only?
- (5) What insects use their front wings for balancers only?
- (6) What insects use their hind wings for balancers?
- (7) What insects fly with both pairs of wings?
- (8) What insects fly with one pair of wings?
- (9) What insects have no wings?
- (10) What insects in the mature state eat animal food?
- (11) What insects in the larval state eat animal food?
- (12) What insects in the mature state eat plant food?
- (13) What insects in the larval state eat plant food?

- (14) What insects in the mature state eat no food?
- (15) What insects build homes for their young?
- (16) What insects show a care for the young in the deposition of eggs?
- (17) What insects abandon their young?
- (18) What insects hibernate in the mature state?
- (19) What insects hibernate in the pupa state?
- (20) What insects spend the winter in the egg?
- (21) What insects spend all their lives above ground?
- (22) What insects spend part of their lives under ground?
- (23) What insects are injurious in the larval state?
- (25) What insects are beneficial in the larval state?
- (25) What insects are harmful in the imago state?
- (26) What insects are beneficial in the imago state?

THE SPIDER

Epeira sp.

GENERAL CHARACTERISTICS.—How does this animal differ most strikingly from the insects? Observe that there is no line of division between the head and the thorax. This united portion is called the *cephalothorax*. How is the abdomen united to the cephalothorax? What insects have a similar method of union?

THE CEPHALOTHORAX.—(1) On the dorsal side of the cephalothorax find the *eyes*. Are they simple or compound? How many? Do you think they are located in the best place? Do you find *antennae*? Draw dorsal view of the entire spider ($\times 2$).

(2) On the ventral side find the *appendages*. How many in all? How many are legs? How many are mouth parts?

Observe the front pair, the *mandibles*. Are they segmented? How do they end at the lower part? How are they attached to the head? What motion or motions have they? These mandibles are called the *chelicerae*, poison fangs. Near the base is the opening of a duct that leads to a gland which secretes a poisonous substance. This gland is perhaps of the same nature as a salivary gland, and the fluid stuns or paralyzes the prey of the spider. Remove mandibles with the scissors.

Behind these are the *maxillae*, with their *palpi*. What are the palpi used for? Are they really a necessary part of the spider's mouth parts? Remove the maxillae with scissors. Do you find the *labium* or the *labial palpi*?

(3) How many pairs of legs? How are they attached to the body? How many segments? Do the legs of the first pair have as many segments as the others? If the insects have three pairs of legs and labial palpi, and the spiders have four pairs of legs without labial palpi, what does this suggest as to the origin of the extra pair of legs of the spider? Remove the tarsus of one of the legs and put it under the low power of the microscope. What covers the leg? Find three hooks at the end. Observe them closely to find the distinct shape of each hook.

Draw end of tarsus as it appears under the low power objective.

Have you ever seen spiders with legs missing? Did you ever see them with some legs short? They have the power of reproducing legs when they have lost them by accident.

THE ABDOMEN.—(1) Examine the dorsal side of the abdomen to see if there is any indication of segmentation.

(2) Look on the ventral side of the abdomen, near its union with the cephalothorax. Do you find small openings? These are the *lung sacs* which the air enters and purifies the blood. How do they differ from the spiracles of insects? Look in the opening, to find if possible, how the blood is purified. On the median line a little further back may be found the opening of the reproductive organs.

(3) At or near the posterior end find the spinning apparatus, which consists of blunt protuberances called *spinnerets*. How many are there? Look closely to see if you can distinguish any markings on the surface. Each spinneret consists of numerous openings through which exudes the material that is hardened by the air into a solid flexible thread. All the threads of the spinnerets unite to produce the *web* of the spider. A small spiracle may be found in front of the spinnerets.

(4) Are these spinnerets evidences of segmentation? Do you think the abdomen has ever been composed of separate segments the divisions of which showed around the body? If so by what process has the segmentation been reduced to its present condition?

Draw ventral side of the abdomen ($\times 4$).

DEVELOPMENT.—(1) The eggs of the spider are usually placed in a *sac*, or *cocoon* surrounded by a silk web. In some species the cocoons are carried around by the mother spider who will sometimes die rather than abandon it. In other species the cocoons are concealed by bark or covered with dirt or pebbles, while some abandon the eggs as soon as they are laid.

(2) When the eggs in the sac hatch, being bound up tightly in the cocoon, the young spiders eat one another until they are large enough to get out or until the mother opens the cocoon for them. The young spiders grow rapidly and molt often, until finally the adult form is reached. The adult form hibernates during the winter under bark, logs, or in other protected places.

(3) Get a young spider, observe it closely and see how it differs from the adult. Draw a dorsal view ($\times 2$).

CLASSIFICATION.—Spiders belong to the class *Arachnida*. This class is composed of the orders *ticks* and *mites*, *scorpions*, *harvest spiders*, and the spiders proper, *Araneida*. This last mentioned order contains all our common spiders, has about thirty-two families which are separated into genera by the position and grouping of the eyes.

HABITS.—(1) Spiders are among the most interesting of animals, and have been observed from ancient times. The following experiments can easily be performed with them.

a. Get a large spider and put it under a tumbler.

b. Place before it a lump of salt, then a lump of sugar, then a piece of bread with vinegar on it. Observe its actions in each case, then put before it a live fly and watch it. Do you think the spider has taste or smell? Sound some musical instruments near it, and see if it gives signs of hearing. Repeat these experiments on the following day. Can it crawl out of the tumbler? Why? How does a spider get to the ceiling of a house?

c. Throw a fly or some other insect into the web of a spider and observe its method of entangling and winding is securely. What does it do with it? What do you think

the web is for? How do the spiders without webs get food?

(2) The webs of spiders are interesting objects of study and may be seen almost anywhere, where special caution is not taken to keep them away. Get a small bit of spider web and put it under the low power of the microscope. Can you tell its structure? Find a spider web out in the open field or garden and study its structure? Can you detect anything like a plan in its formation? If so make a drawing of it. The web of the common geometrical, or garden spider is a good one to study.

(3) Have you ever seen spider webs flying in the air? Where did they come from? Some spiders can sail through the air by throwing out a tangle of their web so that the breeze will carry them with it. Are spiders injurious?

(4) What are the enemies of spiders? Do spiders ever protect themselves? In what ways? Is there a connection between the colors of spiders and their safety?

THE CENTIPEDE

Scalopocryptops, sp.

GENERAL CHARACTERISTICS.—This animal is a harmless one and may be examined either before or after it is killed. It is commonly called the small centipede.

How many divisions to the body Are all alike?

Observe the appendages. How many? Where located? Note the covering of dorsal and ventral sides.

THE HEAD.—(1) Study the head from the dorsal side. Do you find *cycs*? *Antennae*? Where are the antennae located? How many segments in each?

(2) Study the ventral view of the head. What mouth parts are there? Are the mandibles segmented? Where are the mandibles located with reference to the other mouth parts? Are they similarly located in insects? What do these facts teach with reference to the mandibles? Do you find indications of mandibles under the labrum?

THE BODY.—How many segments? How are they joined together? How many feet? Count the segments. How do they end? Look between dorsal and ventral sides for spiracles. How many? Compare this animal with the larva of butterfly? Of beetle?

Make drawing of dorsal side ($\times 2$). Also ventral side ($\times 2$).

DEVELOPMENT.—The centipede belongs to the class Myriapoda and is one of the most timid of the class. Its eggs are hatched into a form similar to the adult, and the animal grows by molting and adding segments back of the head.

HABITS.—Where is this animal found? What does it do when discovered? Do all "thousand legs" act in the same way? From its mouth parts what do you think is the nature of its food? How does the centipede defend itself? Do you think it is poisonous? Do you believe the stories told about the deadly effects of the centipedes of Texas? Why not?

THE CRAYFISH

Cambarus sp.

GENERAL DIRECTIONS.—Crayfish may be found in ponds and streams at any time of the year, except in winter. They may be kept for a short time in a vessel with a small amount

of water at the botton, or they may be preserved in alcohol by placing them in fifty per cent alcohol for a day, and afterward changing the alcohol to seventy-five per cent, and finally ninety-five per cent. If placed in alcohol the shell should be punctured in several places, so that the alcohol may reach the internal parts. It is well to mix with the alcohol a small amount of glycerine, about one fourth of the amount of alcohol, in order to keep the body of the animal soft and flexible after drying.

THE LIVE SPECIMEN.—(1) Observe the general shape. The front division is the *cephalothorax*, and all the posterior part, the *abdomen*.

(2) Note the *walking appendages*. How many? Shape, size, structure? How many does the animal use in walking? What other use is made of them?

(3) Notice the *hinge* in the front claw. Put a pencil in the claw and if the animal grasps it, test the strength of the muscles of the claw.

(4) Touch one of the eyes with a pencil and note what follows. Notice the range of vision of the eye, and also the range of muscular movement.

(5) Study the animal in water, thrust a pencil at it quickly, and note how it darts backward. Study the under part of the abdomen and see how this movement may be accomplished.

(6) Describe briefly the different motions possible to a crayfish and tell how each is accomplished.

THE EXTERNAL PARTS.—(1) Kill the specimen with chloroform, or by plunging it in boiling water. (The former method is better for study of internal structure, while the latter is better for study of external parts.)

(2) The united head and thorax are called the *cephlo-thorax*.

(3) The continuous covering of the two is the *carapace*; above and between the eyes is the *rostrum*.

(4) The hinder, flexible part is the *abdomen*. Count its rings, or *segments*. Bend (flex) the abdomen, and straighten it repeatedly, observing how the segments are joined together and how they move upon one another.

(5) Separate the third abdominal ring (counting from the front) from the rings in front of and behind it. To do this hold the cephalothorax and fore part firmly between the thumb and fore finger of the left hand with the posterior end of the abdomen projecting toward the right hand; then grasping the needle with the right thumb and forefinger, thrust the point of the needle obliquely forward between the third and fourth segments and work it right and left, severing all connection between them; with the scissors cut the membrane between the under sides of the rings and entirely separate them.

(6) In like manner detach the third segment from the second. Observe the following parts:

- a. The upper part — the *tergite*.
- b. The under part — the *sternite*.
- c. The side piece — the *pleurite*.
- d. Two appendages — the *swimmerets*.

Find that each swimmeret consists of a *main stalk* and *two branches*. Examine these branches thoroughly. Lay the ring on its front side and make a drawing of the complete ring. Compare the other rings of the abdomen with the third. Draw ring with swimmeret ($\times 2$).

In the male crayfish the swimmerets on the first abdom-

inal segments are *highly developed*; in the female they are *degenerated* and almost absent. Examine a number of specimens to illustrate this.

(7) The last segment is called the *telson*. It forms the middle flap of the *caudal*, or *tail fin*. Has it swimmerets? Are there swimmerets on the sixth segment? Compare the flaps on the sides of the caudal fin with the swimmerets of the other segments. If they have the same parts and seem to have the same origin they are said to be *homologous*. Are all of the swimmerets homologous with those of the third segment? Draw caudal fin ($\times 1$).

(8) Are the appendages of the thorax borne upon rings? After looking carefully for rings, observe the appendages. Are they homologous with one another?

(9) Remove one half of the carapace with scissors and forceps. This exposes the *gills*. Observe the gills closely, noting structure and place of attachment. Move the legs back and forth and see if there is any indication of a connection between the gills and the legs.

(10) Remove a gill and study its structure under the microscope. Make out a *main stalk* and numerous *filaments*. Study from books or other sources, the method of circulation in the gills and the process of oxygenation of the blood. Make a drawing of gill ($\times 1$); also a diagram illustrating the method of purifying the blood.

(11) Study the last thoracic appendage or hindmost walking leg. Count its segments observing carefully the peculiarities of each. Notice the number of joints and the motions allowed by each. With the forceps seize the basal segment and pull off the leg.

(12) Remove in like manner all the thoracic legs being careful not to leave any part behind on the body. How many gills are present on each? Are any gills left behind? Do you see indications of rings? Lay the legs on a piece of paper in the order that you pulled them out. Compare them all with the first taken out. In the legs bearing claws do you find any new part added, or is the pinching apparatus produced by a change in parts that are already present? How do the legs which bear the big claws differ from walking legs? Compare them segment with segment. Draw, ($\times 1$).

(13) In front of the big legs, or great *chelae*, are several pairs of appendages surrounding the mouth. Probe between them to find the mouth. The appendages in front of the great *chelae* are the hindmost of three pairs of jaw feet called *maxillipeds*. Gently raise them to see how they cover the other mouth parts. Note that these maxillipeds have an *inner* branch covering the corresponding part of the other maxilliped and an *outer* one. Are these branches attached to one another or to a basal segment? Seize the lower part and remove the whole maxilliped. Compare it with a swimmeret of the third abdominal segment. In the same way remove the second and first maxillipeds keeping them in order. Are gills attached to the maxillipeds? Make drawing of gill showing structure.

(14) Anterior to the maxillipeds are the two pairs of *maxillae*. These are very thin and lie close to each other, so that if great care be not taken they will be pulled off together. Insert the forceps deep down and remove them one at a time. Notice at the base of the first maxilla re-

moved, a thin spoon-shaped structure — the *gill scoop*. It lies in front of the gill chamber. Move the second maxilla of the other side to see how it works. The gill scoop swinging back and forth, pushes the water out at the front end of the gill chamber. The water thus expelled is replaced by fresh water, which comes up under the lower end of the carapace about the bases of the legs.

(15) The mandibles are short, hard, toothed, each bearing a jointed appendage which lies in a groove around the mandible. This is the *mandibular palpus*. Closely fitting against the posterior surface of each mandible is a thin, leaflike structure — the *metastoma*. Remove the mandible and the metastoma and lay them in the series with the others. Count them to see that they are all there. Remove the corresponding appendages of the other side, lay them in a row facing those of the side before removed, and make a drawing of the series ($\times 2$).

(16) The long projections in front of the head are the *antennae*. Move them about in all directions, find the large segment at the base, under the head. On this basal segment find a small white cone with an opening at the summit. This is the aperture of the *green gland* in the head which acts as a kidney in throwing off certain waste products of the body. Remove the antennæ with the whole of the big segment. What is the probable use of the *bladelike* branch of the antenna just under the eye? Is there any similarity between the antennæ and the swimmerets? Are they homologous?

(17) Above the antennæ are the *antennulae*. Remove one of them and compare it with a swimmeret.

(18) Look at the base of the antennulæ for a mem-

brane surrounded by bristles called *setae*. This is the entrance to the *ear sac*, the supposed organ of hearing. Probe it with a needle.

(19) Study the *eye*. Note the stalk on which the eye is located. Is it segmented? Is it hinged at the base? Is the eyestalk like a swimmeret? Remove the outer covering of the eye, scrape the inner dark part away and mount the outer part under a cover glass. Examine under microscope. Draw.

(20) After removing all the appendages from the cephalothorax and cleaning the framework, look again carefully for traces of rings. If these can be found, study them carefully at the point of fusion and make a drawing of one side. How does this framework differ from the carapace? From the soft fleshy part of the abdomen? How many rings in the entire specimen? Is there a pair of appendages to each ring?

(21) Study carefully the carapace. Do you find a membrane under the hard crust? Is the carapace homologous with the pleurites of the abdomen? Put a piece of it in boiling water, note result; put a piece in dilute hydrochloric acid, note result. Explain what happened in each case. Has the carapace any connection with the framework of the thorax proper? What do you think is the origin of the rostrum? Of the carapace?

(22) Make large drawings of dorsal and ventral sides.

INTERNAL STRUCTURE.—(1) Place the crayfish, ventral side down, on a block of wood, or in a dissecting tray, and thrust pins through the telson and through each of the great claws. Remove the carapace and the gills, leaving the framework and appendages. In removing the carapace,

be careful that the delicate organs on the dorsal side may not be molested.

(2) This exposes the *heart*, an oblong, whitish body surrounded by a membrane, the *pericardial sinus*. This sac receives the blood from the gills after it has been mixed with oxygen. Carefully remove the sinus and expose the heart. Look for holes on its upper surface and for small, white tubes running from it toward the head. There are *two holes* in the top of the heart, *two* beneath, and *one* on each side. These are guarded by liplike valves on the inside, so that when the heart contracts, the blood is driven out through the arteries to the various parts of the body. The blood on leaving the arteries moves out into the viscera of the body and is finally collected in irregular reservoirs which communicate with the gills. The path of the blood is from the body to the gills, from the gills to the heart, and from the heart to the body. Draw heart ($\times 2$).

(3) The principal arteries that may be found are as follows: *Superior abdominal artery* which passes back from the heart, resting on the reproductive organs and the muscles. Study it carefully and make out the different branches. The *sternal artery* branches off from this near the heart. The *ophthalmic artery* runs from the middle of the ventricle anteriorly passing over the stomach. Find branches running to the stomach and head. The *antennary arteries* arise near the antero-lateral angles of the heart. These supply the antennæ, the green gland and the lateral walls of the stomach. Make a drawing showing the dorsal view of the circulatory system. Through the wall of the ventral side of the abdomen may be seen the inferior abdominal artery. Cut away the wall of the abdomen and follow the

artery posteriorly to the telson and anteriorly to the sternal artery.

(4) The organs extending lengthwise under the heart are the *reproductive organs*. In the female are found the yellowish *ovaries* in which at certain seasons of the year the spherical eggs may be seen. Note the position of the masses and their relation to the other viscera. Examine the tube leading from the ovaries to the surface at the third thoracic leg. This is the *oviduct*. In the male the reproductive organs are similar in shape to those of the female though smaller in size. Study the color, position and shape. The *vas deferens* is the tube leading to the surface at the first thoracic segment. Follow it.

(5) Carefully cut away the roof of the head. Find the stomach with a thin wall in which is a hard framework. Remove the soft tissues from around it. Do you see the *esophagus*, or gullet, extending from the mouth to the stomach?

(6) The large reddish or brownish masses around the posterior end of the stomach are the lobes of the *liver*. Pick one to pieces and study its structure.

(7) Observe the white *muscles* which extend forward from the abdomen along the sides of the body cavity.

(8) Beginning at the anterior end of the abdomen cut through the tergum on each side down to the telson. Seize this roof with the forceps and remove it, cutting the muscles with the scissors if any adhere. The mass that you now see is the mass of abdominal muscles.

(9) Running lengthwise in the middle is the intestine. Follow it up to the stomach. Follow it down to the posterior end, the *anus*, and observe any variations in size. Draw the entire alimentary canal.

(10) Note the shape and outer appearance of the stomach. Probe through the mouth into the stomach, and note the varying hardness of the different parts. Find the insertion of the muscles of the stomach. Are there any pouchlike extensions of the pyloric portions? The organ is *chitinous* in places and resembles the outer carapace. Open the stomach with the scissors. Note the hardened areas and make out the uses of the projections. Draw interior view of the stomach.

(11) The nervous system being on the ventral side has not yet been injured. It consists of a series of ganglia connected by nerve cords. The following may be found:

The *supra-esophageal* ganglion, composed of two ganglia fused together, is under the rostrum behind the antennæ. From this mass the two cords, or *commissures*, pass around the esophagus and unite to form the *infra-esophageal* ganglion. Behind these, the ganglia and commissures extend to the posterior portion. Study them. Do the ganglia correspond to the number of body segments? Do you find the large nerve cords by which the muscles and other parts are supplied with nerves? These are really bundles of nerves which divide and sub-divide until the single nerve only remains to act upon the tissue. Make enlarged drawing of the nervous system.

DEVELOPMENT.—In the early spring the eggs of the crayfish are laid and carried on the swimmerets of the female. When the eggs are hatched the young still cling to the swimmerets until they are able to care for themselves. The shell is molted several times during the growth of the animal and occasionally after it has reached maturity. In molting, the carapace splits and the animal extricates itself

by great physical effort. Accidents frequently occur during molting in which the animal loses one or more appendages, but as they are quickly replaced, it soon recovers its complete form. The hard parts of the stomach are shed at each period of molting. Why? Why does the crayfish molt? What is the condition of the animal when molting has been completed? Read the complete life history of the crayfish.

HABITS.—What food do crayfish relish? How can they choose their food? Can they live out of water? How do they breathe out of water? How do they spend the winter? How do they defend themselves? Do they fight often? Are they courageous when attacked? How do they show it? If they lose appendages how do they reproduce them?

CLASSIFICATION.—Summarize the principal types you have studied, by a comparison, including similarities and differences, of the grasshopper, spider, centipede and crayfish. Tabulate the summary as before.

SIMILARITIES.

| Divisions of Body | Appendages. | Nervous System. | Metamorphosis. | Name of Branch. |
|-------------------|-------------|-----------------|----------------|-----------------|
| | | | | |

DIFFERENCES.

| Name of Type Animal. | Regions of Body. | Number of Appendages. | Respiration. | Name of Class. |
|----------------------|------------------|-----------------------|--------------|----------------|
| Grasshopper. | | | | |
| Spider. | | | | |
| Centipede. | | | | |
| Crayfish. | | | | |

While they are all alike in the characteristics necessary to put them in a single group, a *branch* of the animal kingdom, yet they differ sufficiently to put them in different classes.

The branch to which these four types belong is *Arthropoda*, a word which refers to the segmentation of the legs.

The class to which the crayfish belongs is *Crustacea*, a word which refers to the covering of the animal.

The crayfish belongs to the order *Decapods*, family *Astacidae*, and the Genus *Cambarus*.

The following synopsis of the more common forms of Crustacea is abridged from McMurrich's Invertebrate Morphology. Examples are given under each division.

CLASS CRUSTACEA

I. Subclass ENTOMOSTRACA.—Number of segments varies; abdomen without appendages; larva a Nauplius.

1. Order PHYLLOPODA.—Number of segments variable; appendages with branchiae.

1. Suborder BRANCHIOPODA.—Body plainly segmented and segments of thorax more numerous than six.

Branchipus (sand flea).

2. Suborder CLADOCERA.—Body indistinctly segmented; with bivalved shell; four to six thoracic appendages. *Daphnia*.

2. Order OSTRACODA.—With bivalved shell; body indistinctly segmented; two thoracic appendages. *Cypris*.

3. Order COPEPODA.—Without shell; five pairs of thoracic limbs; many forms parasitic and degenerate.

1. Suborder EUCOPEPODA.—First thoracic segment only fused with head; abdomen cylindrical and segmented except in highly degenerated forms. *Cyclops*.

4. Order CIRRHIPEDIA.—Sessile or parasitic; segmentation indistinct; six pairs of thoracic appendages; pass through Cypris stage *Barnacles*.

- II. Subclass MALACOSTRACA.—Number of segments constant; thoracic segments eight; abdominal seven or eight.
1. Order LEPTOSTRACHA.—With bivalved shell; abdomen with eight segments.
 2. Order THORACOSTRACA.—With carapace covering the whole or a part of the thorax; abdominal segments seven.
 1. Suborder SCHIZOPODA.—Thorax completely covered; thoracic appendages biramous.....*Mysis*.
 2. Suborder CUMACEA.—Last four or five thoracic segments not covered by the carapace; eyes sessile or rudimentary.
 3. Suborder STOMATOPODA.—Last three or four thoracic segments not covered by the carapace; eyes stalked; five maxillipeds*Squilla*.
 3. Order DECAPODA.—Thorax completely covered; five posterior appendages uniramous and three maxillipeds; otocysts in antennules.
 1. Suborder MACRURA.—Abdomen usually well developed.
Crayfish, Lobster.
 2. Suborder BRACHYURA.—Abdomen small and concealed beneath cephalothorax more or less perfectly.....*Crab*.
 4. Order ARTHROSTRACA.—No shell or carapace as a rule; with seven (or six) walking limbs; eyes sessile.
 1. Suborder ISOPODA.—No carapace; first thoracic segment fused with head; body flattened dorso-ventrally; branchiae on abdominal appendages.....*Oniscus* (sow-bug).
 3. Order AMPHIPODA.—No carapace; first thoracic segment fused with head; body flattened laterally; branchiae on thoracic appendages*Gammarus*.

PROTOZOANS.

HOW TO FIND THEM.—Protozoans may be obtained in large quantities by any of the following methods:

(1) In a vessel boil some dry hay in water. Pour contents of vessel into a jar and allow it to cool. Into this infusion put some fresh hay. Amoebae will appear in two or three days.

(2) Take a pond lily or other water plant from the water of a pond or pool and put it in water allowing it to remain a week or more, until the plants are partially decayed. This water will generally contain a ciliate infusorian, *Paramecium*. It will also often contain many other genera of protozoans.

(3) Scrape the slimy mud in the bottom of a pond or pool and place it in a bottle or tumbler with several inches of water on it. Allow it to stand for several days in a dark, warm place, and pour into it occasionally a little fresh water. Many different kinds of Protozoans will generally be found in this and it will often contain *amoebae*, and sometimes *cyclops* (a crustacean), and larval *mollusks*. Protozoans may generally be distinguished by a flattened form and the lack of definite appendages.

HOW TO STUDY THEM.—With a pipette, or medicine

dropper, take some of the water from the above preparations and place it on a glass slide near the middle. Carefully clean a cover glass and put it loosely on the slide. Change the water on the slide as often as necessary. The specimens may be fed by putting water at the edge of the cover glass and letting it run under the slide by capillary attraction.

(1) General Examination: Look carefully at the slide with the low power of the microscope and see how many different forms you can find. Notice shape and variations in size. What determines the shape of the body? Is there a distinct *head*? How are the motions of the body produced? Do you find blood? A heart or organ corresponding to a heart? Do you find gills? Eyes? Nervous system? Do you find an alimentary canal or any part of one? Do they seem to choose their food or the path they travel? Is there a protection for the body? Draw four or five different forms in a general way showing the outline of the organs studied.

(2) The *Amoeba*: This specimen is generally distinguished by its irregular outline and its uncertain motions. Examine it carefully and note its general outline in the different positions. What is its shape? Is the shape the same in different positions? Do you find *pseudopodia* (parts of body extended into feet)? What is the shape of a *pseudopodium*? How many has a single specimen?

Make sketches of the animal at different times showing the pseudopodia.

Distinguish the following parts:

- a. *Ectosarc* (outer, clear, layer of protoplasm). How much of the body does it form?
- b. *Endosarc* (inner, granular mass of protoplasm).

Study the *nucleus*. Position? Shape? Size? Is it in the same relative place in the different specimens? Drop a small drop of aceto-carmine on the side of the cover glass and watch the effect on the amoeba. Is there more than one nucleus?

Find *contractile vacuole*. It may be known by its pulsating movement. Position? Shape? Number? Has it any definite contents? What function does the vacuole seem to perform? Make an enlarged drawing of the amoeba naming the parts.

(3) The Paramecium (slipper animalcule): Examine as you did the amoeba. How does it compare with the amoeba in size? In shape? Does it change its shape during its movement. Find the *cuticle*, or *cell wall*. Note its extreme transparency. Is it present over the entire surface? Is it entire or has it openings?

Find the *ectosarc* and *endosarc* and compare with those of the amoeba. Do you find food vacuoles, *i. e.*, particles of food-ingested substances?

Do you find *contractile vacuoles*? How many? Where situated? Examine several specimens to see if the vacuoles are constant in number and position. Find the *nucleus*, and, if possible, a *micro nucleus* beside it. Note size and position. Compare nucleus with that of the amoeba.

Do you find *cilia* covering the body? Do they cover the body entire? Why? Examine a single *cilium* and draw it. Are the cilia all of the same size and shape?

The *trichocysts* are seen directly beneath the cuticle. How are they arranged? What is their shape and structure?

Do you find the *mouth*? What is its position? Shape? Is the position constant? Is the shape of the mouth perma-

ment? How is the mouth closed? Compare with the amoeba in this respect.

Find the *esophagus* and *anal opening*. Are the positions of the two constant?

Does the animal appear to have a *nervous system*? Does it seem to perform actions of its own accord? Does it seem to be irritated when other objects come around it? Do the cilia on the different sides coördinate in movement? Has the slipper animalcule the sense of touch and of taste?

Make a large drawing of the paramecium showing and naming the parts studied.

NOTE.—If amoebae cannot be found, the white blood corpuscle of the frog or of any mammal may be used, as they have all the common characteristics of amoebae.

(4) The Vorticella: It is likely that some of the slides prepared will show this simple form of life. It may be readily distinguished by the fact that it is bell-shaped in form and has a stem by which it is generally attached to leaves or sticks in the water. Examine under microscope. Note its shape and length and compare it with Amoeba and Paramecium. Do you find the *ectosarc*, *endosarc*, *nucleus*, and *vacuole* as in the Paramecium? Study the base by which the animal is attached. How is it attached? Remove one with a needle. Is it difficult to remove? Do you think it could remove itself and attach itself? Why? Does it grow singly or in colonies? Study the stem. Does it seem to have the same structure as the body? Does the body have the power of movement? Look at the size of the heads. Do you find any in the process of division? Do you find a mouth? Where? Of what use are the cilia? Reproduction may take place by simple fission as in the Amoeba, and

by conjugation of a free swimming head with a stalked head?

Draw several forms and show as much of the structure as possible by the drawings.

Compare *Amœba*, *Paramecium*, and *Vorticella*, bringing out especially the increasing complexity of structure.

SUMMARY.

One celled animals are not only simple and primitive in form, but the life processes in them are carried on with the least mechanism possible. As the entire cell is in contact with the food medium, the organization for nutrition is necessarily almost wanting. Yet there is a perceptible increase in complexity as we go from the *Amœba* to the *Vorticella*.

Other Common Forms: Protozoans are everywhere present and furnish part of the environment in which all animals must grow. The number of species is very great and they inhabit in countless numbers and conditions every part of the known world. They are supposed to have been the first forms of life on the earth, and during this time they have developed many variations in form and mode of life.

Parasites: Many protozoans are parasitic in habit, their size, and simplicity rendering them particularly well fitted for such life. In the human body, the germ of disease which causes dysentery, and the malarial parasite which by multiplying causes malarial fever, etc., are protozoans. *Gregarinidæ* are also parasites and live in the intestines of the centipede, crayfish and other animals.

Marine Forms: The water of the ocean, though clear in

appearance, contains myriads of protozoans. So abundant are they that a celebrated naturalist has said that they furnish food, directly or indirectly, for all the animals of the sea.

Many of these forms are protected by shells, which are secreted by the microscopic animal. In this way they are partially protected from surrounding dangers.

The Globigerinæ are forms that extract calcium carbonate from the sea water and make it into calcareous shells. On the inside of these shells the animal lives and through the perforated surface, protoplasmic arms, called *pseudopodia*, are extended. These animals live in countless numbers in the surface water of the ocean and when they die their shells fall down, forming a mass of calcareous matter at the bottom of the ocean. After a very great length of time has elapsed, this mass solidifies into limestone, or chalk beds. This has been going on for ages and many of such beds have been elevated to the surface, and form the mineral strength of the most fertile soils known.

The Radiolaria are forms with shells of a siliceous nature and their shells form flint beds in the ocean, which may afterward become land.

SPONGES

THE SPONGE SKELETON.—Examine carefully a piece of commercial sponge. Note the location of the smaller and larger openings and their relation to one another. Make out the general circulation of the water in the sponge and make a diagrammatic section of the sponge showing the system of circulatory tubes.

Tear off a piece of the sponge and mount it in water under a cover glass. Are the fibers single threads or branched? Describe briefly the structure and make a drawing showing the points noted.

THE SIMPLE SPONGE (*GRANTIA CILIATA*).—(1) *General Method of Examination*.—The entire specimen should be examined with the unaided eye and then with pocket lens. Keep it in fifty per cent. alcohol in watch crystal while examination proceeds. For making sections after the general work is completed a sponge should be run through the alcohols and stained (see Appendix, III), then mounted in paraffin and cut into thin sections with the microtome. These sections may be mounted in balsam after dissolving out the paraffin with turpentine. Another specimen should be prepared by allowing it to stand twenty-four to thirty-six hours in two per cent. solution of chromic acid. This dis-

solves the spicules leaving the cellular tissue hardened. The decalcified sponge may then be passed through the alcohols and finally cut and mounted as before.

The spicules may be obtained for mounting by boiling a piece of sponge in potassium hydrate (caustic potash) which dissolves the flesh and sets free the spicules. Then after washing thoroughly allow spicules to settle and pour off the water. The spicules at the bottom may be removed with the pipette and mounted on the slides as other material.

(2) Study the shape of the entire specimen. Is it symmetrical? Can you distinguish an upper and lower end? How? Is the sponge attached or free? Is its shape modified to suit this attachment? How? Do you find anything unusual in the shape of any of the specimens? Can you explain it? Do you find evidences of budding? If so, from what part of the parent sponge does it grow? Explain the process of budding.

At the upper end look for a large opening, the *osculum*, surrounded by spicules. Can you tell its use? Do you see anything on the sides which in any way compares with the opening at the end? Do you find spicules on the sides? Put the specimen on a slide and examine with the low power without using cover glass. What do you find? Measure your specimen. Make a large drawing ($\times 3$) showing the points studied.

(3) Cut the specimen longitudinally with the scalpel and examine the internal structure. The osculum at the end should be studied carefully. The internal chamber is the *cloaca*, or *gastral cavity*. What is the shape of this cavity? How far down does it extend? Does its diameter vary? Study a side of the body wall with the high power.

Do you see the spicules? What seems to be their office? Do you find the *radial canals*, or *incurrent orifices* extending outward from the body wall? Draw one half of the sponge as it appears now and show the parts studied.

(4) Examine a slide made according to direction and trace out the parts studied, *i. e.*, the cloaca, radial tubes and fleshy portion. Study the arrangement of spicules and note how they are disposed about the openings. Make a large drawing of the section.

(5) The spicules mounted according to direction may now be studied and the different forms noted. Note in what part of the body each shaped spicule is found? Can you suggest any reasons for these shapes? Draw spicules.

THE COMPOUND SPONGE (FRESH WATER).—(1) Examine a fresh-water sponge. Note the general appearance and compare with the simple sponge just studied. Is it attached or free? Study its surface. Can you find the openings? Of what use are they? Are they all the same size? Do you think they all carry water in the same direction? Explain how a simple sponge may grow into this form. Draw complete form.

(2) Is this sponge soft like the commercial sponge? What causes the difference? Has it fibers or spicules? Remove a small portion of it and find out the nature of its framework. Study the spicules as in the simple sponge. Are they siliceous or calcareous? Why? Draw spicules.

(3) Observe the mottled appearance of the sponge. The small round bodies are called *gemmules*. Where are they located? Remove a few and study them under the low power of the microscope. Note the shape, size and arrangement. Do you find spicules of a peculiar nature

imbedded in the mass of gemmules? Spicules and gemmules may be better studied if a portion of the sponge containing them be placed in weak nitric acid and allowed to remain until the fleshy portion is destroyed, and afterwards mounted. On the outer coat of the gemmule look for the *foraminal aperture* through which the embryonic sponge emerges. Draw gemmules and accompanying spicules. Make a diagram representing a section of the entire sponge.

Read McMurrich's "*Invertebrate Morphology*" on the structure and growth of sponges.

SUMMARY.

(1) What part of a sponge is valuable commercially? Do all sponges have skeletons? Are all skeletons of sponges alike? What determines the commercial value of a sponge?

A sponge represents a simple combination of cells which differ very little from a mass of protozoans; but while each cell of the protozoan performs all the functions necessary to sustain life, the cells of the sponge are slightly differentiated so that different functions for the life of the whole may be performed by cells specialized for the purpose. Although the specialization is slight, and each cell, even when it is enclosed in the mass, gets its own food and in a measure secretes its own protective spicules; yet as the sponge becomes more complex, the organization increases and the cells become more dependent.

This organization of unlike cells which results from differentiation of like cells gives rise to the *metazoans* as contrasted with *protozoans*. The sponges are generally considered the simplest form of metozoans. Read a larger zoology on the life processes of sponges.

ECONOMIC VALUE.—Sponges have long been known as articles of commerce. The valuable sponge is the one possessing the horny, fibrous frame-work and its value depends upon its softness, fineness of fiber and size. They abound in the tropical regions and the ones that are found in the Mediterranean Sea are most highly prized.

COELENTERATES

SEA ANEMONE

Metridium sp.

Observe the shape and general contour of the body. Distinguish between the *upper* and *lower disks*. Study the lower disk. What does its shape and form indicate as to its use? Is the animal free in the water or attached to something? If attached, how? Draw the lower or basal disk ($\times 1$).

Examine the upper disk. Find the *mouth*, the *lips* and the *tentacles*. Are the tentacles arranged in a definite order? Are they of the same length? Is the mouth alike in all parts? Notice the extremities of the mouth to find any thickening or specialization of any kind. Draw the animal from the side showing the cylindrical barrel and the upper disk.

With a scalpel cut the body into two parts at right angles to the barrel.

This exposes the tube on the inside which extends down from the mouth. This is called the *esophagus*. Look below the esophagus for another coelenteric chamber limited by the wall of the body of the animal and divided, or partially so, by radially arranged partitions called *septa*, or *mesenteries*. Examine the *septa* closely. How many extend to the coelen-

teric canal? How far do the others extend? Make out the *primaries*, the *secondaries* and *tertiaries*. How many of each? What seems to be their function?

Make an enlarged drawing of the base of the animal showing the arrangement of the septa ($\times 2$).

Look on the inside of the mesenteries for muscles, small strips about midway between the mesenteries. Between the mesenteries are found the *reproductive organs*, the *excretory organs* and *circulatory fluid* which nourishes the body, which is composed of the digested food and sea water. This is circulated principally by the movements of the body.

Enumerate the motions of the anemone which you think possible from its form and structure.

THE CORAL.—Study the common star coral and see if you can trace any relation between the framework of the coral and the plan of the sea anemone.

Explain the relation, if any be found, and discuss the process of coral building and reef making.

THE FRESH WATER HYDRA

Hydra fusca

Specimens of fresh-water hydra may usually be obtained in pools of water near the school and because of their general distribution are good forms for study. The living forms may be watched in a basin of water, and then hardened in alcohol for sectioning.

(1) Note the general form of the animal. Find the *body*, the *tentacles* and the *base*. Can you make out a definite structure to the outside of the body? If possible find one with *buds* growing from the side. Note the number, arrange-

ment, size and length of the *tentacles*. Between the tentacles, in the central disk, find the mouth. Note its position, size, shape, etc. Make a drawing of the specimen ($\times 5$).

(2) Under a microscope study the tentacles. Note the large circular bodies dotting the surface. These are thread cells or *nematocysts*. Note their size, number in various parts of the tentacles, and apparent structure. Watch them under the microscope using low power. Tap the slide with pencil and note what follows. (This usually causes the extension of the *lasso threads* from the cells). Study the lasso threads and note their uses. In a watch crystal of water containing fresh hydra put an infusion containing paramecium. If the hydra uses them for food notice the method of capture. Draw a tentacle showing a lasso thread.

(3) If a bud is found study its relation to the body. How does it differ from a tentacle? It is a young hydra growing out from the parent hydra. What will finally become of it? This form of reproduction is called *budding*. Hydra reproduces also by eggs, which are developed in the ectoderm of the body. Cut a hardened specimen lengthwise with a sharp scalpel or scissors. Do you find an inner cavity? What relation does it have to the mouth? Has it an opening into the body? What becomes of the indigestible portions of the food of the hydra? Make a drawing of the longitudinal section of the hydra ($\times 5$).

(4) In like manner using a hardened specimen make a cross section of the body just back of the base of the tentacles. Do you find the parts found in the longitudinal section? Draw ($\times 5$). What seems to be the office of the cells on the outside of the body? Of the cells in the sac on the inside of the body?

(5) In the reproduction of the hydra, the egg leaves the body surrounded with a shell-like secretion of its covering. In this condition the egg sinks to the bottom of the water and may remain for sometime before developing further. After a lapse of considerable time, if conditions are favorable, the animal develops into an adult hydra. By this power of remaining inert, the hydra can pass successfully through vicissitudes of coldness and dryness that would otherwise destroy it.

SUMMARY.

The structure of the hydra is very simple. Its body consists of an outer layer of tough cells which is called *ectoderm*, and an inner layer of softer cells, *endoderm*. Between these two layers is a row of scattered, poorly developed cells, called *mesogloea*. In the process of growth from the egg, the outer primitive layer called *blastoderm* is folded at one point producing a saclike interior like the folding in of one side of a hollow rubber ball. From this the animal develops into the adult form with its tough ectoderm on the outside and the hollow digestive tract, surrounded by the cells of the endoderm, on the inside.

The sea anemone is a higher form with a more complicated though similar structure. Its development from the egg is similar to that of the hydra, but the mesogloea is so developed that it forms muscles on the sides of the mesenteries. Indeed the mesogloea is so well developed here that it perhaps deserves the name that it receives in the higher animals, viz.: *mesoderm*. Find the meaning of these words.

The animals that secrete coral are called *coral polyps*, polyp being the name applied to each individual of the col-

ony. The harder parts of the coral are secreted by the ectoderm, but in some kinds as the sea fan and red coral, an additional layer of loosely connected particles of carbonate of lime is secreted in the mesogloea.

THE STARFISH

Asterias sp.

GENERAL SUGGESTIONS.—The starfish is the best representative of this branch for laboratory study. Specimens may be obtained from any of the supply laboratories, and may be kept in two per cent. formalin or seventy per cent. alcohol for an indefinite period. Dried specimens may be made to serve the purpose of this study if soaked for a while before using in hot water. A few specimens with water vascular system injected should be obtained with the others, and kept on hand for reference.

If possible a few specimens of sea urchins and sea cucumbers should be on hand for comparison.

DRIED SPECIMEN.—(1) Examine the specimen as a whole. Note its shape, length of arms, and differences between the two sides.

(Each arm is a *ray*, the sides are *oral* and *aboral*, the central body is the *disk*.)

(2) Note the covering of the aboral side. Remove one of the spines, examine it carefully as to length, attachment, and size.

(3) Note the arrangement of the spines on the oral and aboral sides. Find between two of the arms on the aboral side an oval plate covered with radiating grooves; this is the *madreporic body*. Examine and draw the aboral side ($\times \frac{1}{2}$).

ALCOHOLIC SPECIMEN.—(1) Briefly review the points noticed in the dried specimen. Notice especially the arrangement of the spines on the oral side, and the *ambulacral feet*, in the furrow. Observe the arrangement, size and attachment. Note the arrangement of spines around the mouth.

(2) Compare the spines of different areas as to size, shape and degree of flexibility. Look around the spines for a ring of small projections. These are the *pedicellariae*. Remove one and put it under a microscope. Find a stalk bearing pincherlike parts for grasping.

These are used to clean the spines and remove foreign matter from the body. Make drawing.

(3) Press apart the ambulacral or tube feet and examine the opening, and if a yellowish line is found it is the *nerve cord*. Trace it back toward the disk and find a nerve ring surrounding the mouth. Look in one of the other rays to see if it is present in all. Follow the nerve to the end of the ray and find the *eye* at the end. Draw nervous system. The eye spot is borne on a distinct plate. Draw oral side.

(4) The arm opposite the madreporic body is the *anterior ray*. Cut through the aboral wall near the outer end with scalpel, and from this point cut with scissors toward the disk about two inches. Raise the flap to see that you are not injuring the internal organs and cut to the disk. The branched body under the aboral side is the liver. Along the middle line of the aboral wall is the *extensor muscle*—a yellowish streak. Along the floor of the ray find little *sacs*, (sometimes distended, but generally flat in alcoholic specimens). These *ampullae* are the ambulacral vesicles.

Find the connection between them. Observe the specimen which is injected with coloring matter. Near the base of the ray on each side are the *reproductive bodies*.

(5) Cut along the sides of the two rays lying on either side of the first ray cut, and extend the opening nearly across the disk, being careful not to cut into the body parts. Raise up the parts severed and find the membranous *stomach*.

Pass the bristle in at the mouth and explore the interior.

(6) Observe the lobes of the stomach. Do they extend into the rays? Lift one of the lobes and see if you can find how the muscles are attached. Trace the liver toward the stomach, do you find where the opening is?

(7) Do you find the *anus* on the top of the stomach next the aboral side? Remove the roof from the three rays and make a drawing showing the organs exposed.

(8) Remove the stomach by cutting across the esophagus. This exposes the crooked S-shaped *stone canal* extending downward from the madreporic body. Trace this canal to its lower end and find that it forms a ring—the *circum-oral water ring*—which conveys the water from the madreporic body to the ampullae and thence to the ambulacral feet. This system of circulation is the *water vascular system*.

(9) Cut across a ray in two places about an inch apart and notice all that is included in the part thus cut out. Remove the liver, noting how it was attached to the body wall.

Notice the part through which the ambulacral feet extend.

Probe with a needle the middle portion of the ambulacral

furrow and see if a channel can be found through which the water runs.

(10) Make out how the ampullae are connected with the tube feet. Remove an ampulla and its corresponding foot and make drawing. Make drawing of cross section of ray showing all the points you have found.

(11) Scrape the aboral side of a ray to see if there is anything of a *skin* or of a membranous structure at the base of the spines. Do the spines seem to be attached to the skin? Do the aboral tentacles come off with the skin? Do you find a skin under the hard plate?

The hard part is probably developed from the membrane.

(12) Make a drawing of the water vascular system in the disk and in one ray.

SUMMARY.—The animals of this branch are not much sought after for food by other animals in the ocean. The spiny skin after which the branch is named is generally modified into some form of defense. What is the nature of this defense in the forms you have studied? Some forms, as the sea urchin, act as scavengers, but otherwise they are of no value. Do you notice any general plan in the structure of all? Notice the forms, sizes, and relative freedom of motion of the spines in the various forms.

CLASSIFICATION.—The relationships of the common forms may be seen by the following outline of the Branch Echinodermata:

- Class 1. Asteroidea. Starfish.
- Class 2. Ophiuroidea. Serpent Stars.
- Class 3. Echinoidea. Sea Urchins.
- Class 4. Holothuroidea. Sea Cucumbers.

WORMS

THE EARTHWORM

Lumbricus sp.

GENERAL SUGGESTIONS.—The earthworms burrow in the ground to considerable depth, swallowing the earth removed from the burrow. The digestive juices dissolve out the organic substance from the soil swallowed, and these are absorbed. At night they leave their burrows and crawl about. In the daytime, when at rest, they lie in their burrows with the head at the surface of the burrow. In winter they go deep down into the earth below the freezing point. Fresh specimens may be kept all winter by providing them with earth and a convenient place in which to burrow. Specimens carefully prepared by running them up from fifty per cent. to ninety-five per cent. alcohol should be kept on hand for study of internal anatomy.

EXTERNAL MORPHOLOGY.—(1) Examine a live worm. What is its general shape? Are both ends alike? Which is the head end? Are the two ends alike in shape? How do they differ? Has the worm the same diameter throughout its length? Are both dorsal and ventral sides alike in shape?

(2) Note its color. Is it the same on both sides? Notice a streak of red in the mid-dorsal line. This is the *dorsal blood vessel* showing through the body wall. Can you see blood moving in it? In what direction? Look on the ventral side for a similar red line, the *ventral blood vessel*.

(3) Has it eyes? Where? Can it feel? Hear? Consult reference books to answer these questions.

(4) Note the circular rings which make up the entire body. Count them. Are they all the same size? Each ring is called a segment or *annulus*.

(5) Notice the thick white girdle, the *clitellum*, near the anterior end. How many segments is it from the front end? This is connected with reproduction. Is it in the same position in all worms? Sketch the entire worm.

(6) Kill a worm in chloroform. Strip off the outer skin, or the cuticle, and examine with the microscope. Note markings and thickenings. Sketch.

(7) Place a live worm on a piece of paper and watch its movements. Draw it backward, ventral side down, over the finger. Is there any resistance? With a dissecting microscope look for spines. Where are they located? How many rows? Are they in each segment? These are called *setae* (sing., *seta*). Can you now determine how the animal moves? Boil a piece of the body wall of an alcoholic specimen in caustic potash to free the *setae*. Wash in water. The *setae* will fall to the bottom. Pour off the water and mount some of the residue in glycerine or balsam for study. Draw.

(8) Look for the *mouth*. Where is it? In front of the mouth note a projection, the *prostomium*. Look for the *anus*. Where is it? Look for two slitlike openings in

the fifteenth segment on the ventral side. They are the openings of the *vas deferens*. Exactly in front of these on the fourteenth segment are the two openings of the *oviduct*. These are not very easily seen.

DISSECTION OF THE EARTHWORM.—(1) Kill a large worm by placing it in ether, chloroform, or alcohol. Extend the worm under water in the dissecting pan, dorsal side up. Put a pin through the extreme anterior and posterior ends. With a fine-pointed pair of scissors cut through the body wall on dorsal side near the posterior end. Continue the cutting forward along the mid-dorsal line, being careful not to cut deep enough to injure the organs below. Pin back the body wall on both sides, slanting the pins so that they will not interfere with dissecting. Notice a milky liquid exuding from the cut. With a pipette put some of this liquid on a slide and examine with the high power lens. *White blood corpuscles* should be found moving about in it. Draw.

(2) Notice the dark-colored digestive tract extending from mouth to anus. What gives it its color? Can you now see clearly the dorsal blood vessel referred to above? Trace it out. Notice the oval white bodies dorsal to the digestive tract near the tenth segment. These are *reproductive organs*. Notice the muscular walls between the segments. These were partially cut through in laying back the body wall. What is their relation to the digestive tract? To the body wall? Compare these with the external segments. Note the relation. These portions are called *septa*. These divide the body cavity, or *coelum*, into small chambers. What is the shape of a septum? Represent by a sketch.

(3) Trace the digestive tract from the mouth to the anus. That part extending from the mouth to about the tenth segment is the *pharynx*. From this point to the seventeenth segment is the narrowest part, and is called the *esophagus*, or gullet. This opens backward into a dilated portion, the *crop*. Just behind the crop is another dilated part, the *gizzard*. The remainder of the alimentary tract to the anus is the intestine.

(4) Notice a brownish coat covering the intestine. This is the so-called *liver*.

(5) Remove the digestive tract, being careful not to injure other structures. Just below will be seen the ventral blood vessel already mentioned.

(6) Scrape carefully the other loose tissue from the floor of the body cavity, and below in the mid-ventral line will be seen the white nerve cord. Remove the tissue from it, tracing it forward, being careful not to break it. Now place it under a dissecting microscope, still attached to the body wall, and examine. Is it a single or a double cord? Do you see enlargements along this cord? How many? They are called *ganglia*. Are there any nerves arising from them as side branches? Trace it further forward till you find where it divides, forming a collar around the esophagus. This is called the *esophageal collar*. Just where the cord begins to divide is a large double ganglion, the *infra-esophageal ganglion*. Above the esophagus, where the two parts of the esophageal collar unite again, is the *supra-esophageal ganglion*. It is double also.

(7) You can also now see the *nephridia*, little white coiled tubes between the septa. These are organs of excretion. Study one and see if you can trace it in its windings.

(8) Put a living earthworm in water. Does it seem to be comfortable? What vital process is cut off while it is in the water? Did you find any provision for breathing in the animal? Do you think it breathes? Take it out of the water and see if it revives. Can the earthworm breathe in dry air? Since the blood vessels appear to be near the surface, can you suggest its method of breathing? Why do so many earthworms come to the surface after a rain? Describe the process of respiration.

(9) The anatomy of the earthworm may be better understood by studying a cross section. Use a specimen that has been hardened in ninety-five per cent. alcohol. Cut a piece about two inches long from the center of the worm, and wash out the intestine so that it may be further studied. Cross sections of this piece may be made thin enough for class study by holding the piece between the thumb and forefinger of the left hand and cutting sections with a razor. Examine the body wall. The *cuticle* is a thin chitinous layer of an iridescent luster. Below this is the *epidermis*, which consists of a single layer of cells elongated in the vertical direction. Below this is a layer of connective tissue, the *dermis*. This can scarcely be distinguished. The next layer of the body wall is the circular muscles. The layer within the circular muscles is the *longitudinal muscles*. These are featherlike, and stand at right angles to the circular muscles. They are interrupted, and appear to be divided into bundles. How many? By examining two or three cross sections the exact position and arrangement of the setae may be made out. Can you see where the nephridia open to the exterior? Study the nephridia and see if you can make any clear statement about their shape

and position. In the center is the intestine. Notice a large fold of the intestine hanging from the dorsal side. This is the *typhlosole*. Of what use is such a structure? Just dorsal to the ventral bundle of longitudinal muscles may be seen the nerve cord. Do you see nerves extending to right and left of it? Just dorsal to the nerve cord and ventral to the intestine is the ventral blood vessel. Make a sketch of the cross section, showing all the parts studied.

(10) Cut an earthworm in two, place the pieces in some moist earth in a box. Keep moist, and see what becomes of them.

The earthworm belongs to the class Annelida.

ECONOMIC VALUE.—Every student should read Darwin's "Vegetable Mould" in connection with the study of the earthworm. If we consider the vast work of mixing the soil with subsoil, the opening of passages for water and air, and the working over of minerals unfit for absorption by plants, then we may have some slight idea of the inestimable value of the earthworm to man.

THE NEREIS

The Nereis lives in burrows in sand on the seacoast near low-water mark. In the breeding season it leaves its burrow and swims about.

(1) Note its color. Its length. Its shape. Are the *anterior* and *posterior ends* alike? Has it a dorsal and a ventral side? Note the appendages along each side. Is there a pair to each segment? They are called *parapodia*. Cut off a parapodium close to the body and examine with

a dissecting microscope. Notice the larger fleshy portion. This is a *branchia*. What is it used for? On the dorsal side of the branchia is a small projection called the *dorsal cirrus*. Below the branchia are three sets of *setae*. What is their use? Just below the last bunch of setae is another cirrus called the *ventral cirrus*. Just beneath the ventral parapodium may be seen the openings of the *nephridia*. Draw ($\times 4$).

(2) Examine the anterior end of the body. Note the *prostomium*. Does it project over the mouth? Notice the slender projections from the front segment. These are tentacles. How many pairs? What is their function? Note the two fleshy projections. These are palpi.

(3) Do you find *eyes*? How many? Where are they? Slit the worm open, beginning at the head, for seven or eight segments. Note the large *proboscis*. This is now folded in. It may be rolled inside out like the fingers of a glove. Do this and note the two powerful jaws. Does this suggest its kind of food? What is its food? Draw proboscis showing all the parts.

THE LEECH

Leeches live in water. They may be found on the under-side of old boards, rocks or other objects near the edges of ponds and ditches.

(1) Examine a live leech. Note color. Is the color the same all over the body?

(2) Has it organs of locomotion? Place one in water.

Can it swim? How? Take it out of the water. Can it move? How? Can it live out of water very long?

(3) Notice the *sucker* at the anterior end of the body. Look in this sucker for the *mouth*. What is the sucker used for? Has it another sucker? What is it used for? Do you find an *anus*?

(4) This animal is called a blood sucker. Why?

(5) Draw the entire animal, ventral view. In what respects is it like the earthworm? How does it differ externally? Draw ($\times 2$).

A PLANARIAN WORM

Planaria are usually abundant in fresh water ponds or lagoons at all times of the year. They may be found crawling over water plants such as philotria, chara, pondscum, etc. Pull these plants up with a hook and place them in jars in the laboratory. Soon the sides and the top of the vessel will be covered with planarian worms.

(2) Examine a living animal in water under compound microscope. Note its color. Is the color the same on both sides? Why? Is this of any advantage to the animal? Has it an *anterior* and a *posterior* end? A *dorsal* and a *ventral* side? Describe fully its shape. Is its shape adapted to its mode of life? How? Look on the dorsal front end for *eyes*. How many? Color? Examine the ventral side as the worm crawls over the glass vessel. Do you find a *mouth*? Where is it situated? How does the worm move? How does it hold fast to an object? Notice its slimy feel. Make a sketch ($\times 4$).

(3) Place the animal on a slide and put a cover glass over it in order to flatten it. Back of the middle portion look for a cylindrical muscular body. This is the *pharynx*, which connects with the mouth by a very short *esophagus*. The pharynx can be protruded through the mouth. Do you find a *digestive tract* leading from the pharynx? Trace it to the anterior and posterior parts of the body. How many main pouches has it? Has it an opening to the exterior? How does it get rid of indigestible food material?

(4) This peculiar arrangement of the alimentary tract suggested the name of the order, *Triclada*, to which Planaria belong. What does the word mean? Draw, showing points mentioned ($\times 5$).

(5) Look underneath the *eyespots* for a light-colored ganglionic mass, the *brain*. How many parts to it? Are there nerve cords arising from it? How many? Draw.

(6) With the high power examine the margin of the animal for *cilia*. Do you find any?

(7) Cut a Planarian in two and place the two pieces in a tumbler of water. Examine every day, and note what becomes of them.

Planaria belong to the class Turbellaria.

THE LIVER FLUKE

SUGGESTIONS FOR COLLECTING.—(1) The Liver Fluke, *Distomum*, inhabits the larger bile ducts of the sheep, where it lives upon the biliary matter. This part of the sheep's liver may be obtained from the slaughter house, the bile ducts opened and the contents scraped out into

water. The worms may be cleaned by placing the contents in a warm normal salt solution.

(2) Specimens may also be obtained from the lungs or the urinary bladder of the frog if the above source is not convenient.

(3) To mount *Distomum*, place the worms between two cover glasses on a slide; leave in ninety per cent. alcohol for twenty-four hours; stain faintly in borax - carmine, and mount in balsam.

OBSERVATION.—(1) Examine a living worm under the compound microscope. Do you find the *anterior* and *posterior ends*? *Dorsal* and *ventral sides*? Give reasons for your answers. Is it colored? Why? What gives it its color? Has the surrounding bile a tendency to color it? Describe fully its shape. Does its shape suit its mode of life?

(2) Has it *eyes*? Why? Examine the anterior end, Here is situated the anterior oral *sucker*, in the center of which is the *mouth*. Do you find any other suckers? What are they used for? The mouth leads into a thick muscular *pharynx* lying just behind. That part of the alimentary tract lying just behind the pharynx is called the *esophagus*. Trace the remainder of the-alimentary tract. How many branches? Are there any external openings? Compare the alimentary tract with that of the *Planaria*.

(3) At the posterior end may be seen the *excretory pore* and by careful observation the excretory tube may be traced forward from it for a short distance. Draw the entire worm, showing points mentioned.

State resemblances and differences between *Distomum* and *Planaria*.

DEVELOPMENT.—(1) The *rediae*, one of the stages of development of the Fluke, may be found in the liver of the common pondsnail, *Limnoea*. Break the shell of the snail and remove the animal. Place the body of the snail in a shallow dish of water, and with the aid of the dissecting microscope pick the liver to pieces with dissecting needles. This will probably free the *rediae*.

Note their size and shape. Do you find a *mouth*? A *pharynx*? An *intestine*? *Eyes*? Do they need eyes? Draw ($\times 10$).

(2) Do you find germ cells, or young *rediae* inside the animal? Draw.

When we find an animal living upon another, deriving its nourishment from the latter, the former is called a *parasite* and the latter its *host*. Explain how this applies in case of the snail and the fluke.

NOTE.—This animal has a very interesting life history, which may be worked out by the students from references or given by the teacher in a lecture.

THE TAPEWORM

(1) The Tapeworm is found in the alimentary canal of the rat, the cat, the dog, the rabbit, and many other vertebrates, including man. Sufficient supply for class use may generally be obtained by killing a dog or a cat and looking at once for tapeworms. Open the intestine for one or two feet, beginning at the stomach. Scrape the wall of the intestine closely so as to secure the heads which are buried in the tissue of the canal. They may be kept alive for

several days in common water to which a little white of egg has been added.

(2) Examine the Tapeworm for *dorsal* and *ventral* sides; *anterior* and *posterior* ends. Has it any color? If not, why?

(3) Examine the head (*Scolex*). Do you find anything by which it may attach itself to the intestinal wall? What is the nature of the attaching organ? Do you find a mouth? Has it an alimentary tract? If not, how does it secure its food? Has it organs of locomotion? Does it need any? Is the worm segmented? Each division is called a *proglottid*. Are the proglottids all alike in shape and size? Can a proglottid live free from the rest of the animal? Try it.

(4) Just back of the scolex is the *neck*. Is it segmented? Trace a worm from the head backward, noting differences in segmentation and size of proglottids.

In what respects is the Tapeworm like Planaria and Distomum? How does it differ?

Tapeworms belong to the order Cestoda.

NOTE.—Both Trematoda and Cestoda have interesting life histories which should receive considerable attention on account of economic and medicinal reasons.

CLASSIFICATION.—The following table will give an idea of the relationships of the common animals of this branch.

1. Class PLATYHELMINTHES.

1. Turbellaria. Planaria.
2. Trematoda. Fluke.
3. Cestoda. Tapeworm.

2. Class NEMATHELMINTHES.

1. Nematoda. Trichina.
2. Acanthocephala. Hook-headed worms, parasites.

3. Class ANNELIDA .

- I. Subclass CHAETOPODA.—Metamerism usually well marked; with dorsal and ventral rows of setae along the sides of the body.
 1. Order POLYCHAETA.—Marine forms; with the setae usually upon lateral lobes of the body (parapodia).
 1. Suborder ARCHIANNELIDA.—Without parapodia.
 2. Suborder ERRANTIA.—Elongated swimming or creeping forms; metamerites more or less similar.....*Nereis*.
 3. Suborder SEDENTARIA.—Usually tubicolous; anterior metamerites more or less different from the rest.....*Serpula*.
 - II. Order OLIGOCHAETA.—Aquatic or terrestrial forms; with setae, but without parapodia; hermaphroditic.
 1. Suborder NAIDOMORPHA.—For the most part aquatic; frequently reproducing nonsexually; nephridia serve as reproductive ducts*Nais*.
 2. Suborder LUMBRICOMORPHA.—For the most part terrestrial; not reproducing nonsexually; special reproductive ducts.
Earthworm.
 - II. Subclass HIRUDINEA.—Metamerism well marked; without setae; with anterior and posterior suckers.
 1. Order GNATHOBDELLIDAE.—Mouth with three more or less well developed teeth; pharynx not protrusible.....*Leech*.
 2. Order RHYNCHOBDELLIDAE.—Without teeth and with protrusible pharynx*Clepsine*.
 - III. Subclass GEPHYREA.—Metamerism indistinct; without parapodia.
 1. Order ECHIUREAE.—With setae.....*Echruis*.
 2. Order SIPUNCULACEAE.—Without setae.....*Phascolosoma*.

MOLLUSKS

THE FRESH WATER MUSSEL

Anodonta, or Unio

GENERAL SUGGESTIONS.—(1) The mussel is found in all streams and lakes of this country, and is therefore an easy specimen to procure. If it is desirable to use the common quahog (venus), which is for sale in the markets at all seasons, the following directions with slight additions about the orifices, incurrent and excurrent, will be found applicable.

(2) Specimens may be obtained from the streams and ponds with a rake or dredge of any kind that will reach to the bottom of the water. At certain times they may be found near the shore, and when the water has fallen considerably they may be found in the mud and sand.

(4) If an aquarium, or a tub, be filled with water and a bed of sand be put in the bottom, mussels may be kept alive for an indefinite period.

(4) Have present during the study several shells that may be made to fit together in the right order, and if possible other bivalve shells, as oyster, quahog, mya, and other forms that may be convenient.

(5) The preserved material may be kept in seventy per

cent. alcohol or two per cent. formalin, but at least one muscle should be cut and the liquid allowed to penetrate the interior.

(6) It is desirable that the students go to the natural habitat to collect the specimens if possible.

THE EXTERNAL STRUCTURE.—(1) The Living Animal. Study the animal in its natural surroundings. Note the covering, the *shell*, and the tendency of the animal to keep it shut so tight that nothing can enter between the margins. Does it ever open the shell? Why does it? What makes it close it? Note the *fleshlike fringe* where the shell opens and closes. Touch this fringe with a needle or scalpel. Is it sensitive? Does the animal seem to have control over it? What relation does it assume to the bottom of the water? Watch for movment. Does it move on the sand or through the sand? How is this movement accomplished?

(2) The Shell. Hold the shell in your hand with the narrow edge down and the beak, *umbo*, pointing from you. The part on your right is the right side, the front is the *anterior end*, and the top is the *dorsal side*. Where is the left side? The ventral side? The posterior end? How many parts has the shell? It is called a *bivalve*. Why? Does it have *bilateral symmetry*? Select two shells that fit together like the shells of the animal you have. Examine *umbo* and the *hinge* on the dorsal side, the *margin* on the ventral side. Is there an indication of an *epidermal covering* on the outside of the shell? Notice the lines on the outside. What point do they seem to surround? Are they *lines of growth*? Examine them carefully? How many? Look at the one next the margin and compare its outline with the margin. If the animal should add more to its

shell, what would the present margin become? What has each line of growth been? What does this suggest concerning the past history of the animal? On the dorsal side of the shell behind the umbone, look for the edge of the shell. What color is the shell at the union of the two valves? Is it the same material as the other part of the shell? This is the *spring* of the hinge. Draw outside of the shell, and name all the parts you have found.

(3) Study the inside of the shell. Note the differences between it and the outside. The inside is called *pearl*. Why? Observe the line parallel with the margin, the *pallial line*. Note the hinge and the modification of the shell for it. Can you find out now how the hinge works? Fit the parts of the shell together and find out what use each part is. Draw inside of shell. Break the shell across, or saw it, and note its structure. Can you tell now how each line of growth was added? When a line of growth is added is it added on the margin only? Can you account for the position and shape of the umbones? Draw a section of shell. What is the composition of the shell? Drop a little weak hydrochloric acid on a piece of the shell and note what follows. What does this show?

(4) The Body. (a) Open the shell by thrusting the scalpel under the right valve at the anterior and posterior ends, and severing the rigid, tense *muscles*. The shell now opens. Note the *mantle*, a membraneous covering of the body. Is it attached to the shell? Where? Is it the same thickness throughout? Examine the margin of the mantle, and compare it with the margin of the shell. Do you think there is any connection between them? How is the shell formed?

(b) Follow the mantle carefully around to the posterior

end. Is the upper part still separate from the lower? Note the method of union. Find two *openings, or siphons*. With a needle or bristle trace the openings of each backward toward the body. The water enters at the *incurrent* siphon, bathes the gills, and passes out at the *excurrent* siphon. Which is the incurrent orifice? Which the excurrent?

(c) The *gills* have perhaps already been observed lying flatly on the body under the mantle. Observe them carefully. What is their general appearance? How many on the right side? Are they attached to one another? Can you find out how the water which enters at the siphon reaches them?

Remove a piece of gill with the scissors and lay it on a slide in water. With a needle try to find whether it is single or double. What shape would a section across the gills of one side be? Put a small piece under the microscope and find the minute structure. The *water tubes* may be seen, and if the specimen is fresh the action of the cilia is also visible. Draw the structure as seen through the microscope.

Under the gills may be seen the body. Follow it anteriorly and find the fleshy, *muscular foot*, and the *labial palpi* surrounding the mouth. How many labial palpi? Examine the mouth. Has it jaws or teeth? What kind of food does the mussel eat?

INTERNAL STRUCTURE.—(1) On the dorsal side near the hinge the stringlike *heart* may be seen through the thin mantle wall. Locate it carefully and then sever the mantle wall and remove it from the body. This exposes the *ventricle* of the heart with a tube, *the intestine*, running through it. On either side of the heart find a white membrane extending from the gills to the heart. This is the

auricle, somewhat conical, with the small end at the heart. Do you find its opening into the heart? The blood is gathered into the auricle from the gills, thence to the ventricle, where it is received and sent out mainly through an artery leading forward toward the foot, from which it is distributed through the body and returned to the gills. Has any other animal you have studied a circulation like this? Draw diagram of the circulatory system as it appears to you. Remove the animal from the shell. Observe the large muscles at anterior and posterior ends, the *adductors*, which hold the valves of the shell together. Do you find other muscles at the anterior end attached to the shell back of the anterior muscle? These are the *retractor* muscles. What do they retract? Of what value are they in the movement of the foot? Turn the animal over, fold back the mantle, and make drawing as now exposed, showing and naming all the parts studied.

(2) Using an alcoholic specimen, find the mouth, and insert a bristle into it, and follow with the scalpel, cutting from the outside. The alimentary canal is rather crooked, but may be followed if care is used. Do you find the *liver*? The *kidneys*? Follow the intestine through the heart and find where it empties into the siphon. Which siphon does it empty into? Draw digestive system.

(3) The nervous system is somewhat difficult to trace, but the general plan may be worked out. It is best to use alcoholic specimens for this work. The *cerebral ganglia* may be found at the base of and between the labial palpi. These nerves go to different parts of the body, and with care nerve cords may be traced downward toward the foot to a larger group of pedal ganglia located where the foot

joins the body a little back from the mouth. A nerve may also be traced to the *visceral* or *posterior* ganglion, on the under surface of the posterior adductor. Note the irregularity in the plan of the nervous system. Draw nervous system.

(4) The reproductive organs are found in the posterior region on each side, and open into the gill cavity. The eggs of the mussel are hatched in the gills and the young mussels may be found there if the animal is studied at the proper time. After awhile they pass out into the water through the siphon.

SUMMARY.—(1) What are the advantages and disadvantages of a shell like that of the mussel? Can it be successfully attacked by any animal that you know? What is the origin of the pearl in the shell? The pearl of commerce is usually made by this or some other species of bivalve when something of an irritating nature gets between the shell and the mantle. Why does the animal deposit pearl under such circumstances? Formerly pearls were all obtained from pearl oyster, but recently many of considerable value have been obtained from the mussels of the rivers in the northern part of the United States.

(2) Compare an oyster shell with that of the mussel just studied. Are the valves of the oyster alike? Does either valve show signs of being attached to something? Since it lives in the ocean, would the oyster need such support more than the mussel? Why?

Oyster raising is a great industry in certain sheltered places along the eastern coast of the United States. The greatest menace to the oyster beds is the starfish, which devours the young oysters.

THE SNAIL

Limnaea or Physa

GENERAL SUGGESTIONS.—These animals may be found in almost any lake or stream, and can therefore generally be obtained fresh for study. They may be kept alive in water in the laboratory for an indefinite period by keeping the water fresh and providing for them cabbage leaves or other plants suited to their taste. They may be killed extended in warm water, and put in fifty per cent. to seventy per cent. alcohol, or two per cent. to three per cent. formalin for preservation.

THE EXTERNAL FORM.—(1) Study the living snail in a glass jar. Note its extended body and the relation it bears to the shell. Has it a distinct *head*? Do you find *eyes*? Does the animal have vision? What seems to be the use of the *tentacles*, or *feelers*? Observe the *fleshy foot*. How does it use this for movement? Study the *mouth*? Can you determine how it eats? Does it bite the leaf on which it feeds? Does this animal have a *mantle*? Where? Can you tell how it breathes? Do you find a *breathing pore*? On a living animal note the method of disappearing within the shell. Is the disappearance complete enough to be of any advantage?

(2) The Shell. Is the shell in one piece, *univalve*, or in two pieces, as the mussel? Find the *apex* (the pointed end); the *aperture* (the opening); and the *lip*, or outer edge of the aperture. Do you find *lines of growth*? Begin with the lip and trace the lines of growth around as in the bivalve? How does this shell differ from one valve of the

bivalve? How large was the animal when it began to build this shell? The line around which the shell coils is called the *columella*, and all the part included in the whorls is called the *spire*. Draw shell.

(3) Take an alcoholic specimen and break away the shell to expose the lower part of the body. Find the parts noticed before, and further up notice the *respiratory orifice*. What relation has it to the mantle? With a scalpel cut open the orifice and find the structure of the interior? What seems to be its origin and use? What is the advantage in having it located at the edge of the shell?

(4) Find the *mouth*. Note its position, size and shape. Cut open the flesh surrounding it and look for teeth. What is the use of that ribbon-shaped tongue? Remove it entire with the muscles at either end. It is called the *radula*, and works by moving back and forth like a handsaw. Draw entire radula with muscles. Put a piece of it under the microscope and observe the teeth. Draw.

The systems of digestion and reproduction are situated up in the spire of the shell, with openings near the mantle rim.

REPRODUCTION.—The eggs are laid in thin transparent *capsules*, and may be found in the aquarium where the snails are kept for a short time. These may be studied in a watch crystal under the low power of the microscope, and their development watched from day to day. The shell appears as a cap on a small matrix, and continues to enlarge until it covers the animal, after which it coils as the animal grows. Under the direction of the teacher this life history of the snail becomes a very interesting and profitable study.

Mussels and snails are the most common representatives of the great Branch, Mollusks.

SUMMARY.—What special preparation is made by the snail for its life in the water? Can a snail remain for an indefinite period under water? What change in structure would be necessary to enable the snail to breathe in water? The gastropods that live in the sea have that specialization.

Land snails are used extensively for food, but water snails are not generally considered edible.

Which has a stronger shell, a land or a pond snail? Can you give a reason for this?

The cephalopods constitute another class of Mollusks. They have arms, or *tentacles*, surrounding the head, and are usually destitute of external shell except the *Nautilus* which has a coiled, chambered shell.

Are the cephalopods which have no shell as able to protect themselves as shelled Mollusks? Is passive protection among animals as successful as active, aggressive protection? Give examples of each.

BRANCH MOLLUSCA.—Adapted from McMURRICH.

- I. Class AMPHINEURA.—Visceral hump not developed; bilaterally symmetrical; shell represented by scattered spicules or by a series of calcareous plates; anus terminal.
 1. Order SOLENOGASTRES.—Shell represented by scattered calcareous spicules.....*Neomenia*.
 2. Order POLYPLACOPHORA.—Shell formed by eight plates on dorsal surface of body.....*Chiton*.
- II. Class GASTROPODA.—Visceral hump usually well developed; body asymmetrical; shell univalved and usually spirally coiled, sometimes absent; anus not terminal.
 1. Order PROSOBRANCHIA.—Ctenidia present, situated in front of the heart; auricle in front of ventricle; mantle edge not fused with body.

Dentition taenioglossate.

With creeping habit.....*Strombus*.

With pelagic habit (*Heteropoda*).....*Atalanta*.

Dentition rachiglossate.*Murex*, *Buccinum*.

Dentition toxiglossate.*Conus*.

2. Order OPISTHOBRANCHIA.—Ctenidia frequently absent, when present behind the heart; auricle behind ventricle; mantle when present not fused by its edges to body-wall; shell frequently absent.

Mantle present (Tectibranchia).

Foot with broad flat sole; with creeping habit.....*Bulla*.

Foot with winglike parapodia, pelagic.....*Pteropoda*.

With shell (Thecosomata).....*Styliola*.

Without shell (Gymnosomata).....*Clione*.

Mantle not developed (*Nudibranchia*).....*Doris*.

3. Order PULMONATA.—Ctenidia wanting; mantle fused by its edges to body-wall; terrestrial or aquatic.

Eyes at base of tentacles (Basommatophora).....*Pond Snails*.

Eyes at tip of tentacles.....*Land Snails and Slugs*.

- III. Class SCAPHOPODA.—Visceral hump developed; bilaterally symmetrical; shell cylindrical, open at both ends.....*Dentalium*.

- IV. Class LAMELIBRANCHIA or PELECYPODA.—Visceral hump not developed; bilaterally symmetrical; mantle forms two lateral folds; shell bivalved; anus terminal.

1. Order PROTOBRANCHIA.—Gill a true ctenidium; pleural ganglia not united to cerebral.....*Nucula*.

2. Order FILIBRANCHIA.—Gill filaments elongated and bent upwards at ends; cerebral and pleural ganglia fused.....*Mytilus*.

3. Order PSEUDOLAMELIBRANCHIA.—Gill filaments turned up at ends and with interlamellar junctions; cerebral and pleural ganglia united.....*Oyster*.

4. Order EULAMELIBRANCHIA.—Gill filaments united to form a platelike gill; cerebral and pleural ganglia united.

Venus (*Quahog*).

5. Order SEPTIBRANCHIA.—Gill reduced to a muscular perforated septum between the mantle and suprabranchial chambers.

Cuspidaria.

Heart with two auricles; two nephridia.....*Halotis*.

Heart with a single auricle and a single nephridium.

V. Class CEPHALOPODA.—Visceral hump developed; bilaterally symmetrical; mantle a circular fold; foot (propodium and mesopodium) forming armlike structures provided with suckers and surrounding the mouth.

1. Order TETRABRANCHIA.—With four ctenidia and with external chambered shell.*Nautilus*.

2. Order DIBRANCHIA.—With two ctenidia; shell if external not chambered, usually internal.

With eight arms to foot (Octopoda).....*Octopus* (*Devil Fish*).

With ten arms to foot (Decapoda).....*Loligo* (*Squid*).

VERTEBRATES

THE FISH

Perca sp.

[NOTE.—These directions with but slight alterations will answer for the study of any fish in the markets.]

EXTERNAL MORPHOLOGY.—(1) Straighten the fish out in the dissecting pan and measure its longitudinal and lateral axes. How does the dorsal differ from the ventral side? How is the head joined to the body? How does the right side differ from the left? Animals that have the right and left sides alike are said to be *bilaterally symmetrical*. Has the fish perfect bilateral symmetry?

(2) How many *fins* are there? How are they arranged with reference to one another? The fins at the anterior end on the side are the *pectoral* fins. Examine one carefully. Of what does it seem to be composed? The spines that run through it are called *rays*. Are all the rays bony? Examine a piece that is not bony through the microscope, low power.

How is the fin attached to the body? Are all the fins attached in the same way?

Draw pectoral fin ($\times 2$).

Back of the pectoral fins on the ventral side find a second pair, the *ventral* fins. Examine them and compare with the pectoral fins. Are they separated or attached on the ventral side?

Compare these two pairs of fins to the upper and lower limbs of a person. Back of the ventral fins is found the *anal* fin. Study it and compare it with the others. With reference to the right and left sides, where is it?

Do you find a fin on the dorsal side? Note its shape and position. It is the *dorsal fin*. Is it made of hard or soft spines? Are the rays segmented? How is it attached to the body? On the posterior end of the fish, find the *caudal* fin. Note its structure and compare it with the others. How is it attached to the body? What motions has it? Are the lobes equal or unequal?

(3) Examine the *covering* of the body. Is it like any covering yet studied? Take out one of the *scales*, examine it where it was attached, and examine the skin at the point where it was removed. Does it look anything like the scales on the wing of the butterfly? Note the shape and size of the scales at the different parts of the body. Do the fins and head have scales? Scrape carefully both sides of a scale and place it under the low power of the microscope. What is its structure? Has it grown out from the body like a feather? Do you think it has had a rapid growth? Make a drawing of a scale ($\times 10$). If the scale is round it is called *cycloid*, if it is toothed it is *ctenoid*.

(4) Do you notice spots of coloring in different parts of the body? Is the coloring on the outer parts of the scales or on the skin under the scales? These spots are *pigment cells* and are simply bundles of coloring matter. Can you

determine their shape? Are they the same color in all parts of the body? Do the fins have pigment?

(5) Find the *lateral* line on each side extending nearly the entire length of the fish. Is it on the scales, in them, or under them on the body? Remove one of the scales along this line and examine. Insert a needle in the place to see if the line is continuous. What is its function?

(6) Study the *skin* on the head next to the mouth. Compare it with the skin on the other parts of the body. Observe the covering of the inside of the mouth. How does it differ from that on the outside?

Do you find *teeth*? Where are they located? Do they have a regular arrangement? Study the shape, size and firmness of attachment of a tooth. Compare it with a scale.

Pull the lower jaw down; this will draw out the bones of the upper jaw the *premaxillary* bones. Study their shape, size and attachment, both at the top and at the bottom.

Draw a premaxillary bone ($\times 4$).

Behind the premaxillaries are the bones of the *maxillary* proper. Observe their shape and note how they fit the premaxillary. The lower jaw is composed of the *submaxillary* bones which are similar to the lower jaw bones of other animals.

Do you find teeth on the upper jaw? On the lower? Look in the upper part of the mouth for teeth. If teeth are present there they are situated on the *vomer*. Find the shape and size of this bone.

Notice the covering of the *tongue*. Rub the finger over it to ascertain the nature of the covering. Notice the covering on different parts to find the variation of the *papillae*, or *taste bulbs*. Do you think a fish can taste?

Where is the tongue attached? For what is it used?

(7) Note the location, size and color of the *eyes*. Are they simple or compound? Do you find eyelids? Can a living fish change the direction of its vision? How many *nostrils*? Are they connected with each other or with the mouth? Probe with bristle to find out.

(8) Lift up the gill cover, *operculum*, which lies flat on the surface of the body in front of the pectoral fin. What is the nature of the gill cover? How many bones in it? What is its covering? Of what use is it?

Look just under the gill cover for a membrane which lies close to the edge of the cover and is attached to it further back. How does this membrane compare with a fin? This is the *branchiostegal* membrane.

(9) Beneath the branchiostegal membrane are the red *gills*. Raise them with the needle. How many? How attached? Are they separate from one another? Note shape of each. Note that the gill consists of the bony framework, or *arch*, the *filaments* on the posterior edge, and the *gillrakers* on the anterior side. How do the filaments and the rakers differ from one another? Open the mouth and depress the tongue. How does it affect the gills? What do you think about the principal uses of the gill rakers? Of the filaments?

Explain the process of passing water through the gills of the living fish.

Remove the first gill below the operculum by loosening it carefully at the ends. Is it fastened by a true joint or is it merely a continuation of the arch into the framework of the body? Study the *filaments*. What gives them their red color? Pick out a single filament. Is its color as red

as before? Look up next to the arch for a blood vessel. Is it an *artery* or a *vein*? How is the blood purified in the gill? Study the filaments under the low power of the microscope and also under the high power. Make drawings of each.

Draw entire gill ($\times 2$).

Look on the under side of the operculum for a red spot. What do you think it is? Observe it closely, noting its position, shape, color, etc. (This is not present in all fishes). Do you think it is a rudimentary gill?

Draw a fish from the left side ($\times \frac{1}{2}$).

THE SYSTEMS OF THE VISCERAL CAVITY.—(1) Hold the fish in the left hand with the tail towards you and thrust the point of one blade of the scissors through the body wall between the ventral and the anal fins just in front of the anus (near the anal fin), and cut forward to the ventral fins. Look carefully at the organs within; cut upward toward the dorsal region of the fish as far as the abdominal cavity extends being especially careful not to cut anything but the body wall, as the air bladder lies in this part of the body. Now cut forward to a point a little above the pectoral fin. Turn the flaps forward or cut them off, and note the silvery membrane, the *peritoneum*, lining these flaps.

In the front part of the body cavity is a reddish or brownish mass, the *liver*. Find the *hepatic vein* passing forward from the liver through the thin partition in front. How many lobes to the liver? Turn it aside and find under it a greenish or yellowish sac, the *gall sac*. This sac contains a secretion of the liver called *bile*. With a needle find how the gall sac is connected with the liver. Can you find an opening of the gall sac into the stomach? Into the intes-

tine? What use has the bile?

(2) Lay the fish on the right side and turn the liver downward gently tearing away its threadlike attachments. This uncovers a pinkish sac, the *stomach*. Pass a probe back into the stomach through the mouth. Note its shape and relation to the intestine. When the intestine comes out of the front end of the stomach, it is said to be *caecal*. Is the stomach of this fish caecal? Do you know of any advantage this may be?

Observe the intestine as it leaves the stomach. How does it compare with the stomach in size? As you follow it down does it get larger or smaller?

(3) In many fishes, there are near this point of union of stomach and intestine several wormlike branches matted together. These are *pyloric caeca*. How many? How arranged?

(4) Trace the intestine to its external opening, the *anus*, and notice the thin membrane by which it is held in place. That is the mesentery; observe blood vessels in it. Find a small, deep red body near the intestine, the *spleen*.

Draw entire alimentary canal ($\times 1$).

(5) In this intestinal cavity, you have probably already seen the reproductive organs. These organs vary in size with the season of the year and consist of one structure in the female and two in the male. Examine these as to size, color and composition. In the female search for a small tube, the *oviduct*, leading from the larger mass, the *ovary*. Where does it lead? In the male search for an opening from each of the lobes, or *spermaries* which unite into a *tube* or *duct*, the *vas deferens* as before. Find its place of opening.

Draw reproductive organs of the specimen that you have ($\times 1$).

(6) If the fish is studied during the spawning season, the entire body cavity of the female will be filled with *eggs*. The ovaries will then have to be removed before studying the alimentary canal. In this case the reproductive organs should be studied first.

(7) Back of these and above, is the *urinary bladder*; a small, pink sac. In the upper part of the body cavity is the *air bladder*. Make a diagrammatic drawing of the organs above noted, showing position. Look closely to see if there is any connection between the air bladder and the stomach. The air bladder is supposed to have originated from a fold in the stomach or some part of the alimentary canal. Scrape away the peritoneum and note the thin wall of the air bladder. Do you see blood vessels in it? Remove the air bladder. Of what use is it?

(8) Above the air bladder find the dark red *kidneys*. Trace one of the kidneys to its termination in the urinary bladder. Remove all the organs studied, except kidneys. Draw.

(9) Return to the partition between the body cavities. Notice again the gathering of the blood in the hepatic veins. Cut carefully through it to see the *heart*. Remove the *pericardial* membrane out to the sides. The red angular portion of the heart lying hindermost is the *ventricle*; the darker, more irregular portion lying (when in natural position) above the ventricle, is the *auricle*. The larger blood cavity back of the auricle, is the *venous sinus*, and the light colored body in front of the ventricle is the *arterial bulb*. This narrows forward into an artery which branches, one branch

going to each gill. After passing through the gills they reunite to form the *dorsal aorta* which passes backward just beneath the spinal column, and after going over the entire body returns to the gills. This is called a *single circulation*. Draw heart ($\times 3$). Make a diagram of the circulatory system.

(10) Open the mouth. See the thin membrane forming the floor of the mouth on each side of the tongue. Cut through this thin membrane close to the inner border of the lower jaw. Continue the cutting backward on each side of the gill cover and the branchiostegal membrane and wholly separate them. Turn back this flap and again examine the gill. Note the joints in the gill arches. Where the gills unite above and below are the *pharyngeal* teeth. The bones supporting these teeth are the pharyngeal bones. They represent a fifth gill arch. Where is the gill?

(11) Examine the Nervous System.

a. With a scalpel open the skull from the dorsal side. Note the successive coverings of the cranium (1) a tough *skin*, (2) a *cartilage*, thicker, (3) a gray *soft membrane* of cellular tissue, still thicker. After removing the last the brain is exposed. Observe the color and relative size of parts.

Notice the general shape and structure of the *brain*. How many lobes do you find? Are the lobes in pairs?

Trace the brain back to the *spinal cord*, the white extension from the base of the brain.

Observe the largest lobes of the brain. These are the *optic* lobes. What shape are they?

In front of these are the cerebral lobes called *cerebral hemispheres*. Note their shape, size, location, etc. Lift

these up carefully at the end and find the small *olfactory lobes*, from which small nerve cords may be traced, toward the nostrils.

b. Back of the optic lobes is the *cerebellum*. Note its size, shape and location in socket. The enlargement back of this has important work of its own to accomplish and is known as the *medulla oblongata*. Draw brains ($\times 4$).

c. The nerves to the eye, *optic nerves*, may now be seen by lifting up the olfactory and the optic lobes. How do they appear at the base of the lobes? How many nerves go out from the brain? Trace the nerve to the eye (cut out the skull where necessary). Does the nerve branch before leaving the eye? Remove the eye from its socket and notice the muscles attached. Are they arranged in pairs? How many?

d. Dissect the eye from the front. Cut the *cornea*, or front part, at one side and allow the thin *aqueous humor* to run out. What is the use of this humor? Do you think it could help vision in any way? With the scissors remove all of the cornea. What is now exposed? With a needle lift up this curtain, the *iris*. How thick is it? What is its color? What is the opening called? What is meant by the color of the eye in any animal? Look closely around the edge to see if there is any increase in thickness.

Remove the *iris* by cutting around the eye next to the outer wall. Back of the pupil find a thickened ball of transparent matter suspended in a transparent liquid mass. This is the *crystalline lens* suspended in the *vitreous humor*, of which it is a specialized part.

Remove the crystalline lens and lay it on a piece of newspaper. Can you see the letters through it? How does it affect them?

In the same manner put some of the vitreous humor on a printed page. How does it affect the appearance of the page?

Return to the eye and observe the inside of the ball. Find a filmy gray mass on a black coat. This is the expansion of the *optic nerve*, called the *retina*, over the black *choroid coat* of the eye. Do you find these two coats all over the eyeball? Stick the needle from the outside through the optic nerve into the inside. Where does it penetrate the choroid coat? Scrape the black coating off of the interior of the eye and see if there is anything left. This coat is tough and durable and gives shape to the eye. It is the *sclerotic coat*. Make a large diagram showing a section of the eye from the front to the rear, including all of the parts studied.

- THE SKELETON.—(1) With a scalpel cut down by the side of the dorsal fin to the ribs. Remove the flesh from both sides of the fish from the head to the caudal fin.

Note the arrangement of the *muscles* under the skin and the position of the small bones. Are the spines of the dorsal fin attached to the central back bone, or *skeletal axis*? Are the ventral and pectoral fins attached to the backbone?

(2) The bones to which the pectoral fins are attached form a ring around the body called *pectoral*, or *shoulder girdle*. Are these bones attached on the dorsal side? On the ventral? What is the advantage of this girdle?

(3) Do you find a similar girdle at the ventral fins? Make out its parts as before. This is the *pelvic girdle*.

After cleaning away the entire skeleton remove a *vertebra* from the spinal column about half way between the pectoral and the ventral fins.

Note the main part, the *centrum*, and the processes extending above and below. Above the centrum find a cavity formed by two spines which grow together. This cavity is called the *neural arch*. What do you find in it?

(4) Below the centrum are the ribs branching out so as to form an arch. This is called the *haemal arch* because the main artery of the body runs down the vertebral column in it. Draw an end view of this vertebra.

(5) Remove a vertebra with its processes from the column behind the anal fin. Look carefully for the two arches. Draw ($\times 2$).

(6) These two cavities are in the main the same in all vertebrates. The neural cavity contains the spinal cord and is enlarged to give place to the brain, while the haemal cavity is enlarged into the visceral cavity which contains the heart and alimentary canal.

Make a sketch of the skeleton of the fish showing the location of the parts studied.

REPRODUCTION.—The eggs of fishes are called *spawn* and are deposited usually once each year. The fish generally seeks a secluded spot in which to place the eggs, but when they are hatched or before, they are used for food by other fishes or even by the one that laid them. To offset this destruction a fish sometimes lays thousands of eggs.

(2) Some of the food fishes from the ocean as cod, herring, salmon, often go many miles up the river to spawn. These are breathers of salt water at all other times, and will die if placed in fresh water at any other time than during the spawning season.

Some of the eels, a class of vertebrates lower than fishes, after hatching, go up the rivers and creeks for hundreds

of miles from the ocean and are oftentimes two years old or more when they reach the ocean. Small eels are found in nearly all the streams tributary to the Mississippi river.

SUMMARY.—(1) Watch a fish in water. Can it turn its eyes? Can it lower and raise itself in the water? Can it swim in a definite straight line? Observe the use that it makes of its fins. When the fish is swimming slowly does it use the same method as when moving rapidly? Of what use is the dorsal fin? The anal? Of what use are so many fine bones found in many fishes?

(2) Does a fish swim with the current or against it? If it should go down a stream which direction must its head be? Why?

(3) What constitutes the principal food of fishes? In order to catch a fish what kind of bait must be used? Can the same bait be used for all fishes? Can a fish be deceived with things that are not food? How does that deception take place? What is a game fish?

(4) How do fishes spend the winter? Can they be caught in the winter? How? What is the source of oxygen that the fish gets from the water? Could fishes live in places where the water is frozen over all the year? Why?

CLASSIFICATION.—(1) Notice that the fish has disclosed an entirely new structure to us. As in the arthropods the nervous system extends along the longitudinal axis, but instead of lying down on the ventral skeleton, it lies on the dorsal side and is held up by a succession of large bones articulating with one another so as to form a strong framework, or *backbone*. This framework forms a support for all the organs of the body, and to it are attached bones which form the *internal skeleton*.

The *neural* arch is enlarged in the head to form the skull for the brain while the *haemal* arch is enlarged below to hold the vital organs. Animals with these characteristics are called *vertebrates*.

(2) The class Pisces, or fishes, occupies a median position between the lowest and highest classes of this branch. The principal subclasses are as follows:

(1). Selachians—fishes with cartilaginous skeletons. Examples, sharks and rays.

(2). Ganoids—fishes with cartilaginous and bony skeletons, and usually having ganoid scales. Example, garpikes.

(3). Teliosts—fishes with skeletons composed altogether of bony matter and having cycloid or ctenoid scales. Examples, all common food fishes.

(3) Read about the various food fishes, the manner of catching, preparing, and using them. For what other purpose are fishes used besides food?

Find out all you can about the fish industry.

(4) In order that we may understand the position of fishes in the branch vertebrates, the classes are given below:

(1). Tunicates. 2. Lancelets. (3). Lampreys. (4). Fishes. (5). Frogs. (6). Reptiles. (7). Birds. (8). Mammals.

THE FROG.

Rana sp.

[NOTE.—If the living specimen cannot be obtained nearly all of the following questions can be answered from an alcoholic specimen.]

GENERAL SUGGESTIONS.—(1) The frog is the most common and best known form of the Amphibians. It is harmless and is always interesting to the observer. Specimens for

study can be obtained at almost all times from April to December, and while the structure may be studied at any time, it is desirable to study the development in the spring, when the eggs may be easily obtained and observed in process of change. There should be if possible at least three specimens for each student and at the beginning of the study one should be prepared for the study of the skeleton. If the teacher has a microtome, much interest may be aroused from the study of the egg in different stages of development. Frogs may be kept for an indefinite period by feeding them on small water animals. They are especially fond of crayfish, but care must be observed to keep the larger frogs separate from the smaller, as they do not hesitate to eat a smaller one of their species.

(1) Where are frogs most abundant? When danger approaches what protection do they seek? Why? Can a frog remain under water for an indefinite period? Why? What are its enemies on land? Does it find enemies in water also?

(2) Notice the covering. Is the frog moist after it has been removed from the water for sometime? Is this an advantage to the frog? Can you find out whether the moisture comes from the body or the air? Study closely the color of the dorsal covering. Is it the same in all frogs?

EXTERNAL MORPHOLOGY.—I. THE LIVING SPECIMEN.—Is it the same in the same frog at all times? Can you think of any advantage in the coloration as you see it now? Describe the surrounding conditions suitable to the color of the frog you have before you. If it changes describe the probable cause for such change. Observe the color of the lower surface. What apparent difference is there in the colors of the upper and lower surfaces? Notice on the

sides how they grade into each other. Is the color of the lower surface the same in all frogs? Does it change as does the color of the upper surface?

(3) Observe the frog in a sitting posture. Note the position of the front limbs, and also the hind limbs. Note the disposition of the toes of both front and hind feet. Observe the well defined hump on the back. Pass the fingers down the back and see what makes the hump. Is it similar to the hump on the back of a cat in a sitting posture?

(4) Notice the general shape of the head. Is it joined to a *neck*? Observe and describe the articulation of the head with the body and the motions resulting from such articulation. Note the position and shape of the *eyes*. Discuss these items with reference to the safety of the animal. Have the eyes eyebrows or eyelids? Touch an eye with the finger or a pencil. What follows? Describe the eye cover. It is called the *nictitating membrane*. Do other animals have such a membrane? Compare the frog's eye and the human eye in this particular. Notice the throat, nostrils, and the sides of the body. Can you detect the process of respiration? Describe the process as it appears from this view. What do the movements of the nostrils and throat indicate? Look over the body for indications of heart action. How does it compare with your own pulse?

(5) See the frog jump and study the process of movement. Does it jump straight forward or at an angle? Is there any advantage in this? Is the body adapted for such a movement? In what ways? Watch the swimming process. How do the movements of the legs compare in the two methods of locomotion? Is the body adapted for swimming? In what ways?

EXTERNAL FORM.—(1) In the chloroformed specimen notice the general shape of the body and compare it with that of the fish and insect.

Observe the divisions of the body into head, thorax and limbs; with the fingers try to determine where the bones are and thus trace the main features of the skeleton. Has it a *tail*? Describe briefly the general plan of the framework.

(2) Study the head. Note the appearance of the dorsal side of the head. Find the nostrils, *anterior nares*; note their lining, color and size. Find the ears, *tympanic membranes*; study their size, shape and markings. Between and below the eyes, find a round spot, the *brow spot* or *pineal eye*. Note its location between the eyes and the nose. Look carefully for *eyelids*. Do you find the external parts of the eye similar to those of the fish? Draw the posterior of the head ($\times 2$).

(3) Open the mouth as wide as possible; study the *tongue*, noting its size, shape in front and back, its point of attachment and the freedom of motion possible to it. What use is made of this free motion of the tongue? Is there anything else about the tongue that will help in catching prey?

Remove the tongue and study its surface. Do you find *papillae* or *taste bulbs*? Does there seem to be a regularity about the furrows? Observe the upper part or roof of the mouth. Do you find a soft palate, *the tonsils*? Describe what you find and compare the tongue and roof with like parts of the mouth of the fish. Draw the tongue from the top ($\times 3$) and make a diagrammatic section from the side showing its attachments to the bottom. Study the *jaws*; note shape, size and movement. Do you find teeth in both

jaws? Where? Of what value are the teeth? Does the frog masticate its food? The back part of the mouth, the region of the throat, is called the *pharynx*. Pass a bristle into the nostrils and see where it enters the mouth. Make an opening in the tympanic membrane and insert a bristle through the mouth. This is the *eustachian* tube. With the bristle find an opening into the esophagus and a narrow opening at the front into the *bronchial tube*. Make a list of the openings that communicate with the pharynx and state briefly the use of each.

This prepares us for a study of those systems that are centered in the protected thoracic cavity.

INTERNAL STRUCTURE.—I. THE THORACIC CAVITY.—(1) It is well to dissect the frog under water or in a very weak solution of formalin. Pin the frog securely on the dorsal side. With scissors or scalpel cut along the midventral line severing the thin outer skin from the posterior end of the body to the mouth. At right angles to this line cut on both sides under the front limbs, turn the flaps back as far as possible and cut them off, thus exposing the body wall, the *abdominal muscles*. Note the arrangement of muscular tissue and follow them both ways to their places of attachment. What effect would their contraction have? What position would that give the body? This muscle is called *rectus abdominalis*. Note the broad fan-shaped muscle running from the central portion of the breast bone to the front limb. It is called the *pectoralis*. What is the function of this muscle? How is its work performed? Look in the muscular walls for evidences of circulation of blood. Follow the blood vessels as far as you can. Do you find many blood vessels going to the surface? Of what use can they be at the surface?

Draw this view, showing the muscles and blood vessels.

(2) Open the muscular walls along the mid-ventral line from the posterior end to the shoulder girdle being careful not to injure the soft *breast bone*. Cut across near the middle on both sides and turn back the flaps thus exposing the vital organs. Do you find the *peritoneum*?

II. THE DIGESTIVE SYSTEM.—(1) Open the mouth and pass a probe through the esophagus into the *stomach*. Push the lobes of the liver aside and study the stomach. Note its shape, location, size and color. Compare it with the stomach of the fish. Is it *caecal*? Carefully trace the intestine from the stomach down to the anus. In the first fold find a pale V-shaped mass, the *pancreas*. What is the function of the pancreas? Note the difference between the small and the large intestine and observe the enlargement, the *cloaca*, above the anal opening. Draw the digestive organs, including the liver and esophagus.

(2) Study the liver. How many lobes? Do you find the *gall bladder*? Where? Describe it. Trace the gall duct from the liver to the intestine. Squeeze out the gall into the intestine. Find the *spleen*, a dark red body in the mesentery near the large intestine. Is it connected in any way with the intestine?

III. THE ORGANS OF CIRCULATION.—(1) The *heart* is found above the liver. Note its shape and position. Compare it with the heart of the fish. The lower pointed part is the *ventricular* portion, the upper part is the *auricular* portion. Do these portions appear to be further divided? Study the blood vessels at the auricular end of the heart. The firmer ones are arteries and the flabby ones, the veins. Note the large arterial trunk extending upward and sub-

dividing. Can you tell which division of the heart this comes from? This arterial trunk is called the *aorta*. Find its point of division, from which two branches (*right and left carotid*) go to each side. Dissect away carefully the surrounding tissues and disclose the divisions of each branch. Where does the first branch leave the main artery? Where does it seem to go? It is called the *anterior carotid* and supplies the head. Follow the artery along to the next branch, where it divides going to the lungs and the skin. What is the office of this blood vessel? Is there a reason for its going to the skin? Does this help to explain why the frog can stay so long under water? Trace the third artery, noting its anterior and posterior divisions. Where does the anterior division go? Trace the posterior division back to the formation of the large dorsal artery by uniting with the corresponding branch of the other side.

(2) Follow the dorsal aorta back. Does it give off branches? Where? What is the object of each? Follow it down to the posterior end, and note its separation into two divisions, the *iliac* arteries, which go to the legs.

(3) Trace the veins back toward the heart. Do you find a corresponding vein for each artery? Do you find a dorsal vein in close proximity to the dorsal aorta? Can you trace the ventral blood vessel that was seen before the opening of the body wall, back to the dorsal vein? Study closely the circulation of the kidneys. From what vessel does the blood which enters the kidney come? To which one does it go after circulating through the kidneys? The circulation through the kidneys is called the *renal circulation*. Trace the vein formed from both kidneys forward to the liver and notice the additions made to it from the mesenteries,

This is the *portal vein*. Trace the veins back into the mesenteries and make out their connection with the intestines. This is the portal circulation which carries most of the digested food, as new blood, into the regular channels of the circulation. Follow this large blood vessel into the dorsal vein, now the *postcaval*, and into the right auricle of the heart. Lift the apex of the heart and see the large veins, the *prccaval*, entering the same auricle from the anterior part of the body.

(4) Find if you can a blood vessel to the left side. Trace it back to the lung. Is it divided? You have already found the method of supplying the lungs with blood, now find the passage back to the heart. Compare this method of oxygenating the blood with that of the fish. Make a diagrammatic drawing of the entire circulation.

(5) Remove the heart and study it. The membraneous covering is called the pericardium. Remove it and study the form, shape, and general structure of the heart. Note the number and location of the openings into the heart and the aortic arch going from the heart.

Draw the heart ($\times 2$).

Cut the heart from right to left exposing the inner chambers. How many? The upper ones are the *right* and *left auricles*, the lower one the *ventricle*. Note the structure of each and explain how the work of the heart is expedited by the structure. Study the valves at the base of the auricles and explain their use. Compare the heart with that of the fish. Make an enlarged drawing of the inner view of the heart.

(6) What is the condition of the blood when it flows into the right auricle? What is its condition when it emp-

ties into the left auricle? What is its condition when it leaves the ventricle? Does this circulation of impure blood affect the temperature of the body? How? What is a cold blooded animal?

(7) Slightly chloroform a frog and tie the toes apart on a notched board so that the web may be placed on the stage of the microscope. Under the microscope notice the blood vessels and the blood moving in them. Do you see the arteries and capillaries? Can you distinguish between arteries and veins? Do you see *corpuscles* in the blood? Draw what you see much enlarged. Increase the amount of chloroform until life is extinct and open the body as before. The heart will probably be still pulsating. Watch the movements. Circulation of blood in capillaries may be plainly seen also in the tail of the tadpole.

(8) Remove a drop of blood and mount it on a slide. Notice the pale red circular disklike bodies, the *corpuscles*, and the fluid, *plasma*, engulfing them. Do you find also irregular white masses? These are *white blood corpuscles* and are really living cells, similar in some respects to amoeba, which live in the blood and have an aimless uncertain motion. Draw red and white corpuscles.

(9) The circulation of the kidneys has been described. Remove from the body, the alimentary canal, the liver and lungs, and expose the kidneys and the reproductive organs. Trace the urinary tube, the *ureter*, from the kidneys down to the cloaca. Draw the urinary system. What is the office of the urinary system?

IV. REPRODUCTIVE SYSTEM.—Look close to the dorsal side for reproductive bodies; in the male these are *testes*, rounded, somewhat yellowish bodies; and folded or lobed

ovaries in the female. Trace the connection of each of these with other systems of the body, and with the cloaca. Find the *oviducts*, irregular, somewhat convoluted tubes through which the eggs pass to the cloaca. Is this connected with the ovaries? If not how do the eggs reach the ovaries in passing out of the body?

V. RESPIRATORY SYSTEM.—(1) Remove the lungs from the body, following them up to the mouth and being careful not to injure the larynx. Notice how the larynx fits into the *V-shaped hyoid cartilage*. Draw outer view of lungs.

(2) Open lungs and note the structure. Can you trace the plan of circulation in the walls of the cells or chambers? How is the blood *aërated*? Have you studied another method of cleansing blood in the frog? Compare the processes of respiration through the skin and through the lungs. Do you see anything about the circulatory and respiratory systems to make the frog cold blooded and sluggish?

VI. NERVOUS SYSTEM.—(1) After removing the abdominal viscera just referred to, there may be seen white *nervous cords* on the dorsal side. Observe them closely. Are they arranged in pairs? Trace them from their origin in the vertebral column to the various parts of the body to which they go. Note the difference in size. Do they go singly to the body? A union of two or more nerves forms a *plexus*. How many do you find? One near the posterior end is called the *sciatic plexus*. Trace the nerves to their union into the sciatic nerve which supplies the legs. The one at the front legs is called the *brachial plexus*. Beginning with the nerve in front of the brachial plexus, count the nerves toward the posterior end. They are known by

their position from the *first*, which is called the *hypoglossal*, in order down to the *tenth*. What nerves form the brachial plexus? Find the fourth, fifth and sixth. Of what nerves is the sciatic plexus made? Note the enlargements on the nerves near the spinal column. Nerves coming from the spinal cord are called *spinal nerves*. Turn the animal on the dorsal side and with the scalpel lay bare the spinal cord and the nerves just observed leading out from it. Do the nerves come out by one root? Do you find a *swelling* on the nerve just as it leaves the spinal cord? Draw the spinal system of nerves, showing what you saw on both sides. The *brain* may be exposed by cutting into the soft bone covering it. Remove the bony covering from the cervical vertebra to the front of the skull. Find the tough membrane surrounding the brain just under the skull, the *dura mater*. Remove this and find another softer membrane closely enveloping the skull, the *pia mater*. Do you find these coverings on the spinal cord also?

(2) The lobes of the brain are now exposed. Compare the different parts with those of the fish, in location, name, and size. Beginning with the anterior portion find the *olfactory lobes*, almost hidden by the central hemispheres. Behind the *cerebrum* find the *pineal body*, which in some reptiles supplies a nerve to the pineal eye before noted. What does this fact suggest to you? Find next the *optic lobes* and trace the nerves to the eyes. What are the nerves called?

(3) Find next the *cerebellum* and the *medulla oblongata*. Note the division of the brain into halves. What is such symmetry called? Why? How do the different parts compare with those of the fish? Draw the dorsal view of the

brain ($\times 2$). Turn the brain to one side, cut the nerves that become visible on the under side, and sever the cord below the medulla. The nerves that go out from the lower surface are *cranial nerves*. The olfactory and optic nerves have been noted, the others supply sensory nerves to the organs of hearing, taste and touch; and motion to the different movable parts of the head, and to the heart, lungs, etc. Draw ventral view ($\times 2$).

(4) Examine the *eye*. Find the *cornea*, the *iris*, the *pupil*, and the *optic nerve*. Do you find a *crystalline lens*? Do you find the different coats, the *sclerotic* and the *choroid*? Compare with the eye of the fish. Make a diagram showing the structure of the eye.

(5) Study the *ear*. Examine the membrane, the *tympanum*, and remove it. Look carefully beneath it for the *labyrinth*. Trace the membranes back, find the shape and arrangement of the tube and if possible find the *auditory nerve* at the end. Draw a diagram of the section of the ear.

VII. THE SKELETON.—(1) For this study it is preferable to take a fresh specimen or one kept in weak alcohol or formalin. The flesh should be carefully removed with the scalpel and the bones allowed to remain at for least forty-eight hours in weak potassium hydrate. This will enable one to remove the flesh and leave the bones attached by the ligaments.

(2) Note the general framework of the skeleton; the *head*, the *spinal column*, the *shoulder girdle* and *fore limbs*, the *pelvic girdle* and *hind limbs*.

(3) THE HEAD.—Note the general shape and size compared with the framework. Note the size and position of the upper and lower jaws, the *maxillaries*. Study the mode

of attachment of the lower jaw to skull. Look again for teeth on the jaws.

Make out the following bones of the skull:

a. Beginning with the front of the skull, the one at the top is the *premaxillary*, back of this are the bones of the upper jaw, the *maxillary*, and in the angle of meeting of the maxillaries two irregular bones, the *vomers*. Look on the ventral side of each vomer. What do you find? Are these teeth of any value to the frog?

b. Back of the vomers find the nasal bones which extend back to the angular, quadrilateral girdle bone or *sphenethmoid*. From this the *parieto-frontal* bones extend to the base of the skull. Notice how these bones form a bridge from the maxillaries over the brain.

c. On the base of the skull find the *proötic* bones leading out on either side to the *squamosal*, a triangular hammer-shaped bone which is connected with the maxillary bone anteriorly by the *pterygoid* and posteriorly by a small bone, the *quadratojugal*. Draw dorsal view of skull ($\times 1$).

d. On the under side of the skull find the large cross-shaped bone, the *parasphenoid*, which forms the floor of the cranium. From this bone the slender *palatines* extend to the maxillaries on either side. Note how the skull is composed partly of bone and partly of cartilage. How does it compare with the skull of the young frog in this respect? Do you suppose the skull of the young frog has proportionately as much bone as the older one? Why? What is the difference between cartilage and bone?

(4) THE SPINAL COLUMN.—At the base of the skull look for a large opening, the *occipital foramen*, through which the spinal cord passes into the vertebral column.

Find the *vertebrae*. How many? At the posterior end find the peculiar flat branched bone, the *urostyle*. Separate the fifth vertebra from the others and study the bone. Find the main body or *centrum*, the *neural arch* through which the spinal cord passes, and the *processes* on either side. How many processes are there, and of what value are they? Compare the vertebrae with the corresponding bone of the vertebral column of the fish. Draw lateral and end views.

(5) THE LIMBS.—a. Study the shoulder or *pectoral girdle*. Trace out the sternum, or *breast bone*, the flat shoulder blade, or *scapula*, the collar bone, or *clavicle*, and the *coracoid* by which the pectoral arch is attached to the sternum. Note how the clavicle, scapula, and sternum are braced with reference to one another. Draw the shoulder.

(6) Observe the bones of the fore arm. The *humerus*, the long bone joined to the shoulder, the *radius*, the larger, and the *ulna*, the smaller of the bones of the fore arm grown together; the *carpus*, or wrist bones; the *metacarpus*, a transverse row of cylindrical bones; the *phalanges*, or fingers ending in the smaller tips of the digits. Draw arm. Study the joints, move them back and forth to find the freedom of movement, and note the method of articulation. Sever the tissue at the elbow joint and study it. Note the white *ligaments* which are modified from the covering of the bones. Study their attachment and the method of crossing the joint. Are these ligaments elastic? Note the modification of the bones at the joints. Of what value is it? Note the covering of the bones at the ends. Of what value is it?

Draw the joint showing the things referred to.

The joint at the shoulder is called a *ball and socket* joint;

the one at the elbow, a *hinge joint*; and the one at the wrist, a *compound joint*. Describe the characteristics of each.

c. In the same way the bones of the hind limbs, or *pelvic girdle*, may be studied. Find the bones composing the socket in the spinal column, the *femur* with the ball fitting into it; the double bone, *tibia and fibula*, united but shown by the grooves; the *tarsus*, *metatarsus*, and *phalanges* in order similar to those of the fore limbs. Draw. Is the pelvic girdle an arch? Why do you think so? Draw it and compare with the shoulder girdle.

CLASSIFICATION.—The position of the frog in the branch of vertebrates is given in the study of fishes. It remains to give the classification of the class Amphibians.

Class AMPHIBIA.

Body long, eel-like, with persistent gills.

Hind limbs absent.....Order Trachystomata (sirens).

Gills not persistent, gill openings usually absent.

Tail present, 4 appendages (rarely 2) present. Order Urodela.
(Salamanders).

Body short, larvae tailed, adult tailless, four limbs. Order Anura
(Frogs, toads).

Families of Anura.

1. Thoracic region capable of expansion.

a. Upper jaw toothless, toes webbed — terrestrial. Bufonidae (toads).

b. Upper jaw with teeth, fingers and toes more or less dilated at tips forming disk, order Arboreal. Hylidae (Tree frogs).

2. Thoracic region incapable of expansion.

Toes webbed and usually fingers, upper jaw containing teeth, tympanum conspicuous — Family Ranidae (Frogs).

DEVELOPMENT.—The development of the frog is an easy and interesting subject and should be watched by every student. In the early spring the eggs may be obtained in

almost any pond, and may be identified as small dark bodies floating in a jellylike mass. They should be put in a shallow basin, in a warm room with plenty of sunlight in it, and to insure growth the water should be changed every day.

If everything goes well the student may study the changes that take place from the day the eggs are collected. By putting the eggs under a dissecting microscope or the low power of the compound microscope, the student may see the segmentation of the yolk, the expanding and extending of the mass and finally the appearance of the head and tail of the young frog, or tadpole. The animal now moves about freely, breathes by external gills, and grows rapidly.

Study a specimen every day until the *external gills* give way and the *internal gills* are used. Find how the water reaches the internal gills. Study the structure of the gills under the microscope and make drawings.

Note the appearance of the hind legs. Study their form. Are they perfect when they first appear? Draw the animal in this stage. Dissect to see the structure of the alimentary canal and heart, and the relation of the gills to the heart.

When the front legs appear the gill opening closes. Where do the front legs appear? What takes place then? Do the young frogs spend all the time in water now? Do they spend much of their time on land? What is the food of a tadpole? Of a frog? Dissect the tadpole in which the front legs have appeared. Do you find any change in the digestive system? Study the structure of the lungs. Do they seem to be related closely to the alimentary tract? Do they seem to be folds in the pharynx? Draw. What advantages does this change from water life to land life bring? What disadvantages?

Make drawing of tadpole in various stages of development.

SUMMARY.—What are the principal changes in environment as the frog goes from the water life to the land life? What are the changes of structure undergone to meet these conditions? What are the advantages of the change to the frog? What are the disadvantages? What does this change suggest as to the past history of the frog?

THE PIGEON

Ectopistes migratorius

EXTERNAL MORPHOLOGY.—(1) The pigeon should be killed with chloroform and the feathers removed from nearly all of the body. Lay the specimen down with the head from you and the ventral side up. Note the extension of the vertebral column anteriorly forming the neck, and the short, blunt extension of the vertebral column into the tail.

(2) Observe the shape, form and place of attachment of the wings and legs. Move them to ascertain the range of motion of each. How many principal segments in each? Are the limbs especially modified? Explain. How many *toes*? How located? Study the toes and their freedom of motion. Are the feet webbed? What is the nature of the *pads*? Of what use are they?

(3) Observe the size and shape of the head and its attachment to the neck. Turn it in various directions to test its range of motion. Observe the *nostrils*. How many? Where located? Do you find eyelids? How does a bird wink its eye? Find on the inside lower corner a membrane,

the *nictitating membrane*, which serves the purpose of a third eyelid. Can you find a nictitating membrane in your eye? Find the *ears*. Of what do they consist? Are they protected? Open the mouth by pulling down the lower bill, or *mandible*. Note the method of attachment to the head. Is it attached directly or does it have another bone at the point of union? Move it back and forth to test it. Is the upper mandible movable? Grasp the base of it with the fingers and attempt to move it up and down. Look in the mouth. Do you find a lower and an upper jaw as in the frog? Do you find any indication of teeth either above or below? Observe the *tongue*. Can it be extended like the tongue of the frog? Do you find any indication of *nerves of taste*? Give reason for your answer.

(4) Study the *covering* of the body. Is there a covering where the feathers have been removed? What is it? Study one of the hairlike projections under the microscope. Draw ($\times 2$). Scrape the skin gently with the scalpel, put a portion of the material obtained under the low power of the microscope. Compare it with the *scales* of the fish. Study the various parts of the body. Is it covered entirely with feathers? Locate carefully the feathered and unfeathered areas. Is this feature an advantage to the bird? Study the covering of the legs and feet. How does it compare with the covering under the feet? How do the parts of this covering join on the sides? Draw several of these plates showing this union ($\times 4$). Study the *nails* and the *bill*. What is their method of union with the body? Do they grow out of the body? How do they compare in color, texture and hardness with the scales on the toes and legs? What seems to be the special use of the nails?

(5) Remove a large feather from the wing and study it.

a. Notice the place on the wing from which it came. Is the feather torn from the wing, or does there seem to be a natural depression? Is there anything left in the depression? If so remove it and study it carefully to see if it resembles any other part of the covering.

b. Study the lower part of the feather, the *quill*. Does it show evidence of direct union with the flesh, or does it seem to come out of a socket? Observe the point of the quill. Does it have an opening in it? Is there any evidence there of a direct connection with the body? Cut a section of the quill and observe the interior. Do you think it grew from the inside or the outside? How does the quill compare with the other coverings of the body?

c. The remaining part of the feather consists of the *shaft*, or *rhachis*, extending up the middle of the feather; and the *vane*, or flattened part, attached to the rhachis. Separate the parts of the vane and note their attachment to the rhachis. Do they extend into the rhachis or do they come from the epidermis only? What do you think is their origin? Study the parts, or *barbs* of the vane. Why do they cling together? If you pull them apart, do they return at once to their former condition? Put a few of them under the low power of the microscope. What do you find? The small projections from the barbs are the *barbules*.

Draw several barbules enlarged.

Make a drawing of the entire feather ($\times \frac{1}{2}$).

d. Look among the feathers for an undeveloped feather, the "*pinfeather*." Study its connection with the body. Has the feather emerged? What do the walls seem to be composed of? Cut across the pinfeather. What do you find

on the inside? How does the feather grow? Where does it get its nourishment? Does it have any direct communication with the blood in the body? What causes the difference in plumage in the different birds? Does the pinfeather explain this? Returning to the original feather now can you find any trace of the old pinfeather capsule upon it? When do you think a feather stops growing?

e. How many different kinds of feathers do you find? Those from the last segment of the wing are *primary quills*, those on the next to the last segment are the *secondary quills*, those at the tail are the *rectrices*, those covering the bases of the quills are the *coverts*, and the remainder are the *contour* feathers. Get one of each, put them in a group and study their differences.

f. Make a list of the various kinds of covering found on the bird.

INTERNAL STRUCTURE.—I. The BODY WALL.—(1) Observe the ridge on the ventral side and follow it backward and forward to its limit. With the scalpel cut through the skin on the right of this ridge and sever the flesh from the hard portion. This bone is called the *keel*, or *sternum*. Note its shape. Cut the flesh backward to the end of the bone and pull it outward. This exposes two muscles. What is their shape? What are their relative sizes? One is called *pectoralis major* and the other, *pectoralis minor*. Can you tell to which muscle each name belongs? How are the muscles attached to the keel bone? Follow them up to the wing and find how they are attached to the wing bone. Where the muscle ends in a whitish tissue is it a part of the muscle or something added to the muscle? This whitish substance is called a *tendon*. What seems to be its origin?

(2) Remove the muscles from both sides of the sternum and expose the bones connecting it with the framework of the body. Observe the union of these bones with the sternum. Is there a movable joint? Is there anything between the bones at their union? What is it? These are the *coracoid* bones, and they unite with the *scapulae* which run back over the ribs. Do you find another bone present in front of these? Note its shape, length and way of attachment. What name is generally applied to it? It is the *clavicle* which in other vertebrates forms a principal part of the shoulder girdle, but in the bird it is not as highly developed as the coracoid bones.

(3) Loosen the coracoid bones from the shoulder, cut away the ribs from the side of the sternum and remove the sternum, the coracoids and the clavicles. This exposes the internal organs. With the scissors cut the skin up to the throat and spread it out on the sides.

II. THE VITAL ORGANS OF THE VISCERAL CAVITY.—

(1) Beginning with the head, find the opening at the back of the mouth. Loosen the sides of the jaw, note the *esophagus*, and follow it down the neck, loosening it from the surrounding organs as you proceed. Running along by the side of the esophagus will be found the *trachea*, or *wind-pipe*, which may be separated from the esophagus and studied apart.

(2) Is the esophagus the same size all the way down? What is the object of the enlargement? What is it called? What advantage does it give the bird? How does the bird swallow? Can it swallow with head down? Why? Tie a string tightly around the esophagus, behind the crop, cut the esophagus in front of the string, and remove it. Ex-

amine the contents of the crop. What do you find? What does it show concerning the food of the pigeon?

(3) Observe the base of the *tongue*. Do you find a bone there? What is its shape? Through an opening in this, find the *trachea*. Is it open or closed? In life is it open? When the bird swallows its food, does it go directly into the esophagus or does it pass first over the trachea? Do you see an apparatus there to prevent the food from passing into the trachea? Insert a tube into the trachea and inflate the lungs. Do the entire lungs come up at once, or do they expand part at a time? What part first? Observe the trachea from the throat down to the lungs. Is it the same size all the way down? Where is it largest? The enlargement at the top is called the *larynx*, and the one just above the lungs is called the *syrix*. The latter is the place where the organ of voice in birds is located. The divisions of the trachea are called *bronchi*. Are they the same size?

(4) Study the pear-shaped organ, the *heart*. Carefully lift up the lobes of the lungs and see if there is any connection between the lungs and the heart. Do you find blood vessels running to and from the heart? How can you tell which vessels run to the heart and which ones run from the heart? Find the *pulmonary artery* and *pulmonary vein*. Do you find the *great aorta*? Follow it as far as you can, noting the branches that go out from it. Find the *venae cavae* — the large veins that gather the blood from all parts of the body, and bring it back to the heart. On which side of the body is it? Why?

(5) With a small stout cord tie in two places each of the vessels carrying blood to or from the heart, as far from

the heart as you can. Draw the cords tightly, and after a secure knot is made, cut off the blood vessels between the cords and remove the heart. Preserve the heart in alcohol for further study.

(6) Remove the lungs and dissect them further. Follow the *bronchial tubes* out in their subdivisions as far as possible. Do you see tubes other than bronchial tubes in the lungs? What are they? (Blood vessels). How can you tell them from bronchial tubes? Remove a small piece of the lung and place it under the low power of the microscope. From its appearance and from what you have found out, of what do you think the lung is composed?

(7) Study the *alimentary canal*. Trace the esophagus down to the slightly dilated *stomach*. Observe the tube closely to find traces of *muscular bands* or *coats*. Do you find any such structure at the end where it has been cut off?

Below the stomach is the *gizzard*, the large rigid body lying in the folds of the alimentary canal. Turn it to one side. Where does the alimentary canal enter? Where does it leave the gizzard? Is the gizzard *caecal*?

(8) The part of the alimentary canal lying just back of the gizzard is the *duodenum*. In a fold of the duodenum is the *pancreas*. What work is performed by the pancreas? Where are the ducts leading into the intestine? The *liver* has already been noticed perhaps. What part of the body cavity does it occupy? Turn the lobes aside and find the *gall sac*. What does it contain? Of what use is it? How does this liquid get into the alimentary canal? Find two ducts leading from the liver to the duodenum. Note the folds in the intestine below the duodenum. How are they held in that position? What is the nature of this mem-

brane? What is it called? Observe the blood vessels in it. Where are they smallest? Where largest? Where do they carry the blood? These vessels unite in the *portal vein*, which carries the absorbed food to the liver, from whence it goes to the heart. Follow the alimentary canal down to the *cloaca*, the enlargement at the anal portion. In front of the cloaca is the *rectum*, which extends from the small *rectal glands* to the cloaca, and in front of this extending to the duodenum is the *small intestine*.

Place the parts of the digestive system that have been studied so that they can be seen and make a diagrammatic drawing showing all in their proper relation.

(9) With a small cord tie the small intestine in front of the rectum in two places and sever the canal between them. Remove the alimentary canal. Cut off the gizzard and examine the arrangement of the muscles on the outside. The hard, light-colored portion acts as a cartilage for the attachment of muscles. How many muscles can you find on the outside? Cut the gizzard across at right angles to the edges. Note its internal structure. What do you find in it? How does the pigeon masticate its food? Have you found a similar contrivance in any other animal?

Draw cross section ($\times 1$).

(10) The *reproductive organs* are found in the dorsal side. The male is distinguished by two oval bodies, the *testes*, and the female by an *ovary* which often has eggs of different sizes in it. Sometimes these show all the different stages of development. These reproductive organs are connected with the cloaca by a duct, the *oviduct* in the female, and the *vas deferens* in the male.

Draw reproductive organs ($\times 1$).

Behind the reproductive organs, lying in the cavity of the roof of the body, are found the soft *kidneys*. What is their position? How many? How many divisions in each? Do you find a duct leading from the kidneys? Where does it go?

Draw kidneys ($\times 1$).

II. THE HEART.—Cut open the *pericardium* if it has not been already destroyed. Note the rough outside and the soft inside enclosing a thin oily substance. This lubricates the heart while it is engaged in its ceaseless work of pumping the blood through the body. Can you tell which is the right and which is the left side of the heart? Lay the heart down with the point toward you and the blood vessels from you. Trace the line of fat around the upper part of the heart. Above this are the *auricles*, small chambers with flabby walls. Can you find blood vessels opening directly into them? How many empty into each? Which side of the heart is the hardest? Compress it with the fingers to find out. The soft side is the right side and the hard, the left. Lay the heart before you in its natural position and draw ($\times 2$). Cut the end off about a half inch from the point. Note the relative development of the right and left ventricles. Why is this? Look at the upper part of the heart. From which ventricle does the great aorta come? From which does the pulmonary artery come?

The blood leaving the aorta is carried by the arteries to the capillaries in all parts of the body and comes back through the *venae cavae*. What ventricle sends it? What auricle receives it? The blood leaving the pulmonary artery is carried through the capillaries in the lungs and comes back through the pulmonary veins. What ventricle sends

it? What auricle receives it? Through how many openings? This is a *double circulation*. Are there any markings on the outside of the heart which show the boundaries of the ventricles? Cut the heart through from right to left, severing the auricles and ventricles. Note the openings between the auricles and ventricles. When the blood comes into the left auricle, what hinders it from running into the left ventricle if it be expanded? When the ventricle contracts, what hinders the blood from going back into the auricle? Look just below the auricle to find some *valves* which are forced together in the contraction of the ventricle and prevent this. Notice how they are anchored to the walls of the ventricle. These are called the mitral, or *bicuspid valves*. In like manner the valves on the right side are called *tricuspid valves*. Can you give a reason for the names? With a probe find where the blood leaves each of the ventricles through the arteries? The blood goes rapidly through the body and the temperature is eight or ten degrees higher than in any other animal. The heat is made in the capillaries, where the oxygen is used in burning up waste tissue. Explain the process.

Draw the heart thus exposed ($\times 2$).

Make an outline of the different systems and organs in the visceral cavity.

III. THE SKELETON.—(1) The skeleton may now be stripped of all the flesh so that the bones may be studied.

(2) The *shoulder girdle* has already been found. Remove the last remaining bone, the scapula, with the wing. Place it beside the coracoid and clavicle already removed to see how the girdle is made to support the wing. Observe the wing bone, the *humerus*, its shape, length, attachment

to the coracoid, and freedom of motion. Note the wing bones, *radius* and *ulna*, which are below the humerus. Observe their form, size, relation to one another. Note the peculiar extension of the ulna back of the joint. Of what advantage is this? Below are found the *carpus*, *metacarpus*, and *phalanges*, strangely modified into a hand in which the phalanges are short and degenerated.

Draw bones of wing ($\times 1$).

(3) The pelvic girdle may be studied in the same way. The bones of the leg are *femur*, *tibia*, *tarsometatarsus* and *phalanges*. Do you see any indication of a fibula? Can you find the place of union of the tarsus and metatarsus to form the tarsometatarsus? How are the phalanges arranged? Make a drawing of leg ($\times \frac{1}{2}$).

The bones forming the pelvic girdle are: (a) the *acetabulum*, which receives the head of the femur; (b) the *ileum*, which extends a considerable length before and behind the acetabulum; (c) the *ischium*, projecting horizontally backward from the acetabulum; (d) the *pubis*, which extends downward and backward on the ischium. These bones are very much modified to suit the peculiar structure and habits of the bird. Study and explain the relation of the habits of the bird to its structure.

(4) The *spinal column* may next be studied, beginning at the head. Sever the head from the first vertebra of the neck, being careful not to injure the bones. Note that the spinal column consists of four regions: (a) the *cervical vertebrae*, sixteen in number; (b) the *thoracic*, five in number; (c) the *sacrum*, fourteen or fifteen vertebrae fused together to support the ilium; (d) the *caudal*, four or five free ones and a terminal *pygostyle*.

Remove the eighth vertebra and study it separately. Note the *centrum*, the *neural arch*, and the *transverse processes*, which are really small ribs. The opening at the base transmits the cervical artery. The other irregularities are called *zygapophyses*. Of what use are they?

Draw end view ($\times 2$).

(5) The first vertebra next to the head is called the *atlas*, and the second *axis*. Study their relation to one another and how they fit together. Can you see why the respective names were given? Have all the vertebrae true ribs? Observe how the ribs project from the spinal column, and also how they are supported.

(6) Study the skull. The opening into it from the spinal column is the *foramen magnum*. The bones surrounding this are the *occipitals*. The bar connecting the front with the back part is the *quadratojugal bar*. At the back end of this is the quadrate bone attaching the lower jaw to head. The upper part of the skull is composed of the *parietal*, the *frontal* and the *nasal* bones, ending in the *premaxillary*, or upper mandible.

Draw the under and upper surfaces of the skull.

IV. THE NERVOUS SYSTEM.—(1) Cut off a portion of the roof of the skull, being careful not to injure the eyes or the internal parts. This exposes a portion of the *brain* which is similar in appearance to the brains of the other animals studied, but is more compact and fits its cavity closer. Remove the surrounding bones and lay the brain bare.

(2) Examine the surface of the brain. Can you name the parts? How do the parts compare with the same parts of the brain of the frog? Of the fish? What part is most

highly developed here? Find the *pineal body* (in the angle between and behind the *hemispheres*), the *optic lobes*, the *olfactory lobes* and the *medulla oblongata*. What are the uses of each?

Draw dorsal view ($\times 2$).

(3) Cut the brain along the cavity between the hemispheres, thus exposing the right and left halves. How many cavities do you find? The front one is the *third ventricle*, the next the *Sylvian aqueduct*, and the last, the *fourth ventricle*.

Draw left half ($\times 2$).

(4) Trace the nerve to the eye. What do you find when you trace it back to the brain? This crossing is the *optic chiasma*. Remove part of the bone from around the eye socket. Note the lining of the eye and the eyelids. Are the eyelids movable? Are they both movable to the same degree? Break away the bone until the muscles are exposed. How many pairs of muscles? Can you find the muscle of the nictitating membrane?

Dissect the eye. Do you find the parts of a perfect eye? Describe each of the parts. What is the difference between the iris of the fish and that of the bird? Can birds see as well in the night as in the day? What structure of the eye enables some birds to see better at night than others?

(5) Note the roots of the *cranial* nerves as they leave the brain for different parts of the head. Do the places to which they go suggest their function? Do you find nerves leading off from the *medulla oblongata* and the spinal cord? What are they called?

CONSCIOUS OR UNCONSCIOUS ACTIVITY.—(a) The organization of the nervous system of the pigeon, consisting

of ganglia and nerve threads, is essentially the same as in all of the other animals studied. The ganglion in the head is called the brain, and is supposed to be the thought center, but is not always the largest ganglion in the invertebrates. The ganglia, composed of gray matter, are supposed to produce on irritation a certain *nerve force* which is conveyed along the nerve threads like electricity along the telegraph wire. In the higher vertebrates if the irritant is without the nervous system, and more especially if it is without the body, the force which originates in the small ganglia is sent toward the brain, and if it reaches it, produces a *sensation*. If the nerve force is originated within the brain, as in thinking, the force, if carried outward by the nerves to the muscles, produces *motion*. Hence we see the connection between sensation and motion. This is *conscious activity*.

(b) However, there are many activities that do not depend upon the brain, but are carried on by the nerve centers below the brain, the principal one of which is the medulla. The *beating of the heart*, the *digestion of food*, and the *secretion of fluids* by glands are of this class. All of the processes which are connected directly with the sustenance of life are carried on without the brain, and in a manner in which the animal is unconscious. There are many kinds of unconscious activity some of which are partly conscious. Do all animals have conscious activity? Do all have unconscious activity?

V. REPRODUCTION.—(1) The pigeon is reproduced from eggs which are deposited in a nest carefully built in some secure place, and are cared for by the mother pigeon until they are hatched. The eggs of a hen will answer the purpose for study quite as well as those of a pigeon.

(2) Boil an egg about four minutes, or until it is hard. Note the outside covering first with the unaided eye, then with the magnifying glass. What is the general shape of the egg? What is the nature of the surface? Break the eggshell and pick it off without injuring the membrane beneath. Study this membrane as you did the outer shell. Does it have the same general appearance? Does it have the same texture? Do you think this membrane has grown to its present size? Has the shell grown, or was it merely deposited? Cut the egg across at right angles to its longer axis. What do you find in its composition? Draw ($\times \frac{1}{2}$).

(3) After the egg is deposited it remains inert until subjected constantly for a considerable time to a temperature equal to that of the body of the bird. How is this secured? When this condition is reached, the embryo which has already begun to grow, enlarges, using in the meantime the yolk and the white for food, until finally it bursts the shell and comes forth in all respects like the adult except in size. In its immature condition it is fed by food prepared by its parents until it is able to select its own food.

(4) In the development of birds the egg during the period of incubation passes through the fundamental process of segmentation, as do the eggs of all other animals. The first layer of cells developed on the outside of the yolk is called the *blastula*, or *blastoderm*, which, after folding in at one end leads to the development of the three primitive germ layers already referred to, the *ectoderm*, the *mesoderm* and the *endoderm* (called by some authors, respectively, *epiblast*, *mesoblast* and *hypoblast*).

From the ectoderm arise the cuticle and its modifications, the entire nervous system, including the brain, spinal cord

and nerves, parts of the eye and the bones of the internal ear. From the mesoderm arise the muscular system, the organs of the circulatory system, the bones of the skeleton and the reproductive system. From the endoderm arise the lining of the digestive tract, the liver and other glands, and the lungs. Each part appears as an aggregation of cells in its own particular location, and grows by further development until it is complete and united with other developed organs around it. Sometime before the chick leaves the egg the organs are all completed and in perfect working order. When it leaves the egg it is essentially like the adult form, which it becomes in a greater or less time by nutrition and growth.

(5) The nesting of birds is a most interesting characteristic and can be studied in the field with great profit. Do all pigeons build nests alike? Do all sparrows? If conditions should change, do you think the birds would change their way of nest-building?

HABITS.—Why are pigeons usually found around barns or cotes made for them? Are they ever found wild? Do they migrate in the winter? Are they gregarious or solitary? Are doves gregarious? Do doves migrate? Why do some birds migrate? How do doves defend themselves from their enemies? How do other birds defend themselves? What kind of food does the pigeon use? Do the shapes of the bill and toes indicate any specialization for food-getting?

CLASSIFICATION.—The pigeon belongs to the great class, *Aves*, which includes all living genera of birds and some of those found fossil. The different orders of birds are classified mainly on the

structure of the bill and toes. The following classification is simple and though old, will be found of value in the classroom.

I. Sternum smooth; wings rudimentary.

Subclass I, Ratitae. *Ostriches*.

II. Sternum keeled; wings well developed.

Subclass II, Carinatae. *Doves*.

Orders of Carinate Birds.

1. Wings small and short; diving birds.

Pygopodes. *Penguins, grebes and loons*.

2. Wings long, pointed; anterior toes webbed.

Longipennes. *Petrels, Gulls and Terns*.

3. Feet wholly webbed, including the inner toe.

Steganopodes. *Pelicans and Cormorants*.

4. Bill lamellate, i. e., both mandibles with teethlike projections.

Lamellirotres. *Ducks and Geese*.

5. Waders; legs long, naked above heel, bill usually long and slenderGrallatores. *Cranes and Snipes*.

6. Land birds; four toes, three in front, one behind, tibia often spurred.....Gallinae. *Domestic Fowls, Quail and Grouse*.

7. Toes alike, 6; bill horny and convex at tip.

Columbae. *Pigeons and Doves*.

8. Bill curved, hooked and large; feet large; not yoke-toed.

Raptores. *Hawks and Owls*.

9. Feet yoke-toed; bill stout, strongly hooked..Psittaci. *Parrots*.

10. Toes in pairs, two in front, two behind; wings with ten primaries.....Picariae. *Woodpeckers*.

11. Perching and singing birds; feet adapted for grasping; hind toe opposed to others.....Passeres. *All common birds*.

Following is a synopsis of the Families of Order Passeres from Jordan's Manual of the Vertebrates.

Families of Passeres.

A. *Tarsus with its hinder edge rounded*; encircled by a single horny envelope divided into scutella anteriorly and on outer side. this sometimes extending all round (though separated by a seam along inner side), but often widely separated on inner side, or behind, or both, the intervening space occupied by granular scales, reticulations, or plain naked skin; musical apparatus imperfect;

primaries 10, the first about as long as second. (Clamatores.)

B. Inner toe free at base from middle toe; tarsus not reticulate behind; bill hooked at tip, with long rictal bristles.

Tyrannidae, *The Flycatchers.*

AA. Tarsus with its hinder edge compressed, forming a sharp, nearly undivided ridge (except in the Larks, which may be known by the long, nearly straight hind claw); musical apparatus highly developed; primaries properly ten, but the first short, or spurious, or sometimes rudimentary and misplaced, so that but nine are evident, in which case the first developed primary is about as long as second. (Oscines.)

C. Hinder edge of tarsus not compressed, rounded and scutellate like anterior edge; hind claw very long, straightish; developed primaries 9.....Alaudidae, *The Larks.*

CC. Hinder edge of tarsus compressed, forming a sharp ridge, for the most part undivided.

D. Primaries apparently but 9 (the first minute and displaced); the first developed (*i. e.* second) primary about as long as the next; bill not hooked at tip.

E. Bill not fissirostral, the gape little longer than the culmen; outer primary never twice as long as inner.

F. Bill "conirostral," stout at base, with the commissure forming a more or less distinct angle at base of bill, "the corners of the mouth" drawn downward.

G. Bill rather long, often longer than head, without notch at tip or bristles at the rictus.

Icteridae, *American "Orioles,"* and *"Blackbirds."*

GG. Bill shorter than head, often notched near tip, and usually with bristles at the rictus.

Fringillidae, *The Finches.*

FF. Bill not truly conirostral (the corners of the mouth not evidently drawn downward).

H. Bill stout (conical in our species, the cutting edge with one or more lobes or nicks near its middle); nostrils placed high, exposed; (plumage chiefly red or yellow, in our species).

Tanagridae, *The Tanagers.*

- HH. Bill rather slender, not conical; angle of gonys not before nostril.
- I. Hind claw short and curved, mostly shorter than its toe; tertials not elongate, not nearly reaching tips of primaries.
- Mniotiltidae, *The Warblers.*
- II. Hind claw long and straightish, mostly longer than it toe; tertials much elongate, nearly reaching tips of primaries. .Motacillidae, *The Wagtails.*
- EE. Bill fissirostral,—the culmen very short, the gape very broad, its length more than twice the culmen; wings very acute, the outer primary more than twice length of innermostHirundinidae. *The Swallows.*
- DD. Primaries evidently ten, the first developed, but short, rarely half the length of the next; (first primary obsolete in some Vireos, known by the slightly hooked bill).
- J. Tarsus distinctly scutellate.
- K. Tarsus not longer than middle toe with claw; bill short, depressed; (head crested; tail tipped with yellow, in our species).
- Ampelidae, *The Chatterers.*
- KK. Tarsus longer than middle toe and claw (or if not, other characters not as above).
- L. Bill strongly hooked and toothed at tip, somewhat like a hawk's bill.
- Laniidae, *The Shrikes.*
- LL. Bill slightly hooked at tip; plumage more or less olivaceous.
- Vireonidae, *The Vireos.*
- LLL. Bill not evidently hooked at tip.
- M. Tail feathers stiff, pointed; bill decurved.....Certhiidae, *The Creepers.*
- MM. Tail feathers more or less soft and rounded.
- N. Nasal feathers directed forwards, usually covering the nostrils.
- O. Large birds; (wing more than 4).

Corvidae, *The Crows and Jays*.

OO. Birds of small size; (wing less than 4).

P. Bill not notched.

Paridae, *The Nuthatches and Titmice*.

PP. Bill notched toward the tip, very slender.

Sylvidae, *The Old World Warblers*.

NN. Nasal feathers erect or directed backward, not covering nostrils; bill rather slender, the culmen convex; first primary not very short.

Troglodytidae, *The Wrens and Mocking Birds*.

JJ. Tarsus booted, without distinct scutella except near the base; rictal bristles present.

Q. Birds of small size; (Wing less than 3); young unspotted.

Sylvidae, *The Old World Warblers*.

QQ. Birds of moderate size; (wing more than 3); young spotted.

Turdidae, *The Thrushes*.

SUMMARY.—Why is the normal temperature of the body of a bird several degrees higher than that of any other animal? Do you suppose it would be warmer if it were stripped of its feathers? Does it hurt a goose to pluck its feathers? What would become of the feathers if they were not plucked?

Do you think birds are sensitive to pain? Do you think the singing birds should be killed? Do you think wings and bodies of birds are proper ornaments for hats?

How does the food of birds reach the blood? How does the blood reach and become part of the tissue? How does the tissue waste away and get out of the body?

What is the process of locomotion in birds? Is it any harder for a bird to fly than it is for an insect? Why? Can a bird move in the air without flapping its wings? Are any of the birds awkward flyers? Is there any connection between the keel and the flight of the bird? Why?

Make a list of the birds that migrate. At what time of the year do they migrate? Why do they not all migrate? Make a list of the singing birds and of the birds that do not sing.

Are birds friends or enemies of insects? In what way do they affect insects, and at what stages of development?

Are birds injurious or helpful to man? Should they be protected by law?

Make a list of birds that are helpful to man, and also a list of those that are injurious.

Investigate the following birds; find where each belongs in the classification given, and also whether useful or injurious to man:

| | |
|------------------|---------------|
| Owls. | Bluebird. |
| Kingbird. | Swallow. |
| Jay. | Warbler. |
| Crow. | Lark. |
| Robin. | Woodpecker. |
| Oriole. | Thrush. |
| Phoebe. | Pigeon. |
| Cuckoo. | Goose (Wild). |
| Blackbird. | Vireo. |
| Bobolink. | Martin. |
| English Sparrow. | Woodpecker. |
| Hawk. | Quail. |

THE RABBIT

Lepus sylvaticus

GENERAL SUGGESTIONS.—The common rabbit is the most satisfactory mammal to dissect, and hence this study is introduced here. The directions will apply with but few changes to the cat or dog. If the specimens can be obtained alive without being wounded, they should be studied to find out movements, favorite positions, and keenness of eyesight and hearing.

Kill the specimen with chloroform or ether, and when it is quite dead cut the left jugular vein to relieve the body of a part of its blood. If the instructor so desires, the arteries and veins may be injected, but very satisfactory work may be done without injection.

I. EXTERNAL FEATURES.—(1) What colors are found on the body, and how are they distributed? What colors are present when viewed from the front? From the rear? Of what value to the animal is the white color of the tail?

Note the hair on the different portions of the body. Where is it the longest? The thickest? Note the hair on the face and the nostrils. Of what value are the *bristles*? Are they all the same length? Look below the nostrils at the parting of the lips. Of what value is it? Note the location of the *eyes* and *ears*. Does this arrangement benefit the animal?

Study the covering at the toes of the feet. Is it of any value to the animal? How? How many toes on each foot? Compare the *claws* of the front and hind feet. For what are the claws used?

(2) Cut the skin around the neck just back of the head, and pull it over the head. Is the skin the same thickness on the dorsal and ventral sides? Why? Notice the muscles running to the ears. Note how they meet on the neck. To what are they attached? What motions have the ears? Of what value are these movements? Notice the ring of cartilage around each ear. Describe it. Remove the skin from the head. Do you find indications of *bilateral symmetry*? What are they? Cut down through the muscles and see if you find other indications of bilateral symmetry.

(3) Remove the *brain* in the following manner; Insert the bone forceps or scissors into the skull just over the base of the ear and cut forward to a point between the eyes. Cut from the base of the other ear in like manner to the same point. Then cut across at the base of the skull and remove the bone. If the cutting has been carefully done the brain will be uninjured. Remove the remaining bone at the base of the skull, exposing the *medulla oblongata*. Cut the spinal cord just behind the medulla, lift brain from back forward, cut the nerves as far from the brain as you can, and finally remove the brain and put it in sixty per cent. alcohol or in Mueller's fluid. Put the brain aside for future study. Observe the inside of the brain cavity. Do you find joints? What kind? Compare with brain cavity of frog and bird. Explain the differences.

(4) At the base of the skull note the articulation of the first cervical vertebra, the *atlas*, with the two projections, the *occipital condyles*, of the skull. Twist the head to find out the freedom of movement. Study the articulation of the second cervical vertebra, the *axis*, with the first,

What provision do they have for articulation on the ventral side? On the dorsal? Twist the first vertebra on the second. Do you find the "axis"? Is it attached to the first or the second vertebra?

II. ORGANS OF THE THORACIC AND ABDOMINAL CAVITIES.

(1) Open the skin along the *mid-ventral line* extending from the breast bone to the pelvic arch. Sever the skin forward to the neck and remove the skin from the entire body. Notice the blood supply to the skin in the region of the fore limbs, and also in the region of the hind limbs. Is the skin attached loosely or closely to the body? After removing the skin, note its softness. Would it make good *fur*? Why?

(2) Study the distribution of blood vessels in the superficial muscles of the body on both dorsal and ventral sides. Make note of any peculiar or prominent vessels.

(3) Look for indications of bilateral symmetry on dorsal and ventral sides. If it is a female, count the mammary glands on either side and note their location. Study the muscles of the body as now exposed. Name as many as you can from your knowledge of the muscles of the frog. Do you find any which are not present in the frog? (See page 165.)

(4) With a sharp scalpel open the abdominal wall from the breast bone to the pelvic arch. Look for the lining of the cavity. What is its nature? What is it called? Note the general position of the abdominal viscera and their method of folding. Do they seem to be segmented? Of what use can that *constricted* form of intestine be?

(5) Sever the ribs by cutting the cartilaginous attachment along the side of the sternum. Pull them slightly

apart. Find and notice position of the following things in order: *Lungs, heart, diaphragm, liver, stomach, and intestines*. Make a diagram of all the organs exposed.

(6) Study the *diaphragm*. Note its structure in different parts. What use is made of that peculiar arrangement of muscular fibers? Is the liver attached to the diaphragm? Describe the liver. How many lobes? Look under the large lobe on the right hand side for a depression in which is located the *bile sac*. Trace its duct down into the mesenteries below the liver. Note the shape, location, and size of the *stomach*. Is it *caecal*? At the distal end of the stomach find the *duodenum* which folds back behind the stomach then runs forward again for some distance. Lift the stomach lightly and study the *mesenteries* attached to the concave side. Find the *pancreas*, a light pink, fat-like mass in the mesenteries, in the fold of the duodenum. Trace the *duct* from the liver to its entrance, about a third of an inch from the origin of the duodenum. Look for the duct of the pancreas further down, beyond the bend.

(7) Tie the esophagus tightly with a string just above the stomach and cut it above where it is tied. Notice a large blood vessel, which divides going to liver and stomach at the base of liver. Cut the mesenteries near the stomach and the duodenum, and gradually unfold and pull away the alimentary tract. Sketch the stomach ($\times \frac{1}{2}$). Follow the duodenum until it passes insensibly into the small intestine and thence into the *caecum*, a large, constricted body, which ends in a thick fingerlike tube called *vermiform appendix*. Note the circulatory vessels in the constriction of the caecum and their connections with the mesenteries. Measure the caecum. Note the entrance and the

exit from it, and make a drawing of it ($\times \frac{1}{2}$). From the caecum onward the alimentary tract is called the *large intestine*. Note its sacculated form in the upper part, becoming smoother in the lower. The lower part of the canal is called the *rectum*. Measure the length of the entire alimentary canal, approximating as nearly as possible the length of the esophagus, and make a diagram showing and naming the different parts of the entire system. Tie the lower part of the alimentary canal and sever it at the *anus*. Remove the canal, tie the duodenum in two places about an inch apart. Cut out a small section between, and study the structure of the canal. Find the outer *serous coat*, the inner *muscular ring*, and the *mucous lining*. What use has each? This illustrates the structure of the entire canal. Draw an end view ($\times 2$). If alimentary canal were shorter, how would it affect digestion? If longer? What then destroys the bilaterality of the abdominal viscera? Make a list of the parts of the alimentary canal, and give the probable uses of each. (This item is optional and requires a lecture by the teacher or the use of reference books on physiology.)

(8) The alimentary canal having been removed, the *urinary* and the *reproductive systems* are plainly shown.

(a) If the specimen is a female, note the *ovaries* and the *oviducts* converging toward the dorsal opening.

(b) If it is a male, find the *testes* and the *vas deferens*.

Find the kidneys in the dorsal part of the abdominal cavity. Note their relative position. Are they opposite? Is there any advantage in their arrangement? Remove the fat from them and trace the urinary ducts down to the bladder at the pelvic arch. Draw the renal and reproductive

systems, showing their relation. Tie the bladder at its base and remove it, cutting behind the place tied.

(9) CIRCULATION AND CIRCULATORY SYSTEM.—(a) Cut the diaphragm away and study the heart. Where is it? Is it an advantage to have it on the side rather than in the middle part of the body? Note its shape and relative position with reference to lungs and esophagus.

(b) Note the large dark blood vessel, the *vena cava*, extending from the liver across to the heart. Where does it enter the heart? Lift up the lobes of the liver and trace the *vena cava* back and find the *hepatic* vein running from the liver into the *vena cava*. Look in the mesenteries which have been cut from the stomach and intestines for a large dark blood vessel which seems to be formed from the veins returning from the alimentary canal. Trace it to the liver. It is the *portal vein*. What does it contain besides impure blood? Trace the large vein backward and note the veins coming from the kidneys, the *renal veins*, to the place where the veins from the legs unite to form it. Do you notice any sudden change of size? Where?

Trace the veins on the right side of the heart forward toward the head. Do you find a union of two veins just anterior to the heart? The vein from the head, the *right jugular*, unites with the vein from the shoulder, the *right subclavian*. The union of these forms the *right anterior vena cava*. Trace it to the right auricle. On the left side find a similar vessel, the *left anterior vena cava*, formed by the union of the left jugular and the left subclavian veins, and crosses at top of left lung, emptying into the right auricle. On the left side find a similar vessel, the *left anterior vena cava*, formed by the union of the left jugular

and the left subclavian veins, and crosses at top of left lung, emptying into the right auricle. Make a diagram of the venous circulation as now shown.

Follow the left jugular vein and find, near its entrance into the vena cava, a large white blood vessel opening into it. This is the *thoracic duct*, which contains a large part of the drain of the body and the unassimilated food from the intestines. Trace it back to the mesenteries below the liver. It is the principal duct of a great system of drainage and cleansing, which works over the partially waste matter and part of the new food by passing it through glands called lymphatic glands. The pink gland just anterior to the heart, the *thymus*, is one of them. The circulation through this cleansing system is known as the lymphatic circulation.

Find the dark blood vessel running from the heart to the lungs. Where does it seem to leave the heart? It is called the *pulmonary artery*. Find the place of division into *right* and *left* pulmonary arteries. How many branches of these arteries do you find in the lungs? Do you find returning blood vessels from the lungs to the heart? They may be distinguished in a specimen not injected, by a lighter color and thinner walls. Trace these returning veins, *pulmonary veins*, from both lungs into the heart. How many? Where do they enter? Make a diagram of the circulation of the blood in the lungs. What work is done by the lungs?

Tie the posterior vena cava between the heart and liver in two places, about a half inch apart, and sever it between the ties so as to prevent bleeding. In the same way tie the vena cava above the kidneys. Remove the liver.

Carefully cut away the thymus gland from above the heart and expose the arteries, which are more firm in tex-

ture and lighter in color than the veins. Find a large curved blood vessel, *aorta*, coming from the heart and curving back on the dorsal side. From what part of the heart does it come? On top of the arch a short distance from the heart find a large branch turning to the right of the animal, the *innominate artery*. This soon divides, sending one branch, the *left carotid*, to the left side of the neck and head, and divides into the *right subclavian*, going to the right side and shoulder; and also the *right carotid*, going to the right side of the neck and head. Trace these as far as you can without mutilating the specimen. Returning to the aorta, the *left subclavian* artery leaves the arch beyond the innominate artery and goes to the left shoulder. Trace it as far as you can. Just beyond the left subclavian on the aorta there arises the first pair of *intercostal* arteries. Others arise between each pair of ribs. From the subclavian arteries on either side, an artery is seen running posteriorly under the ribs. These are the *mammary arteries*, and they return to the mammary veins which were seen on the outside of the muscular wall.

(f) Trace the aorta, which is called the dorsal artery, backward, lifting the left lung, to the posterior part of the body. Just back of the diaphragm it gives off the *coelic artery*, which further divides, giving one branch to the liver and one to the stomach. Further back it again divides, furnishing the *renal arteries* to the kidneys, the *femoral arteries* to the hind legs, and the *lumbar arteries*, which go dorsally to furnish blood to the strong muscles of the back. Trace these arteries as far as you can conveniently, and make a diagram representing the arterial circulation as you have it exposed from the left side of the animal's heart.

(g) Make a tabulated list of the blood vessels on the left side and those on the right side of the heart. Tabulate the similarities and differences between the veins and arteries. How does the blood reach the arteries from the veins?

(h) Cut the veins and arteries as far from the heart as you can and remove the heart with the delicate pericardium that surrounds it. What blood vessels can you trace from and into the heart? Make a drawing from the ventral side showing all the tubes at the top of the auricles. Make a diagrammatic drawing of the entire circulatory system.

(i) Dissect the heart as in the pigeon. (See page 185.) Find all the valves. Make out their uses. Draw interior view ($\times 4$).

(10) THE RESPIRATORY SYSTEM. — (a) Above the lungs notice the trachea. Remove carefully the enveloping membrane, exposing the *trachea* from the lungs to the mouth. Are there muscles connected with it? What is its position with reference to the esophagus? Is it open or collapsed? Why? Trace the trachea down to the lungs, and note its divisions into the right and left *bronchi*. Do these tubes further divide? How many lobes to the lungs? Lift the lungs and sever them and the tracheal tube from the esophagus, being careful not to cut the lung tissue. Study the muscles at the top of the trachea which surround the *larynx*. Remove the lungs and the trachea, being careful not to injure the bone at the base of the tongue. Spread out the lobes of the lungs and make a diagram of the ventral view.

(b) With a blowpipe inflate the lungs through the larynx. Note the amount of expansion.

(c) Remove a ring of the trachea about half way down. Is it the same structure throughout? Draw the end view. What is the advantage of this structure? Of what value is the cartilage in the respiratory system? Cut a piece of the lung tissue as thin as possible (with microtome, if there is one in the laboratory; if not, with razor) and study under the low power of the microscope. Do you find both air tubes and blood tubes? Explain. Draw.

(11) VOCAL CORDS AND VOICE.—(a) Study the larynx. Note its situation in the throat. From the ventral side note the *epiglottis*, a movable membranous cartilage at the top. Behind is the *thyroid*, a heavy circular cartilage extending almost around. On the ventral side find the *cricoid*, a flat thick cartilage in between the ends of the thyroid; and behind are the lobes of the *arytenoid* cartilage. Draw dorsal and ventral views of larynx.

(b) Look down into the larynx and see the voice box, in which can be distinguished a pair of membranous *vocal cords*. Where are they attached? How are they tightened and relaxed? Locate the muscles that do this. For what are these cords used? Make diagram representing them open and also closed. Compare voice box with that of bird. (See page 182.)

III. THE NERVOUS SYSTEM.—(I) Remove the kidneys and the muscles of the interior of the back, looking for white cords, or *nerves*, which may be found near the vertebral column. Do you find a nerve cord on either side with occasional attachments to the spinal cord? These constitute the *sympathetic nervous system*. It is connected with ganglia in different parts of the body, the largest of which is the solar plexus in the region of the stomach.

What is the use of the sympathetic nervous system?

(2) Just under the femoral artery of the hind leg find the *sciatic nerve*, which may be traced into the leg and also back to the vertebral column. What is the office of the sciatic nerve? Do you suppose the rabbit ever has an attack of *sciatica*? Look at the vertebral column on both outside and inside and find the spinal nerves. How many? To what parts do they go? Make a diagram of the spinal system as you have found it.

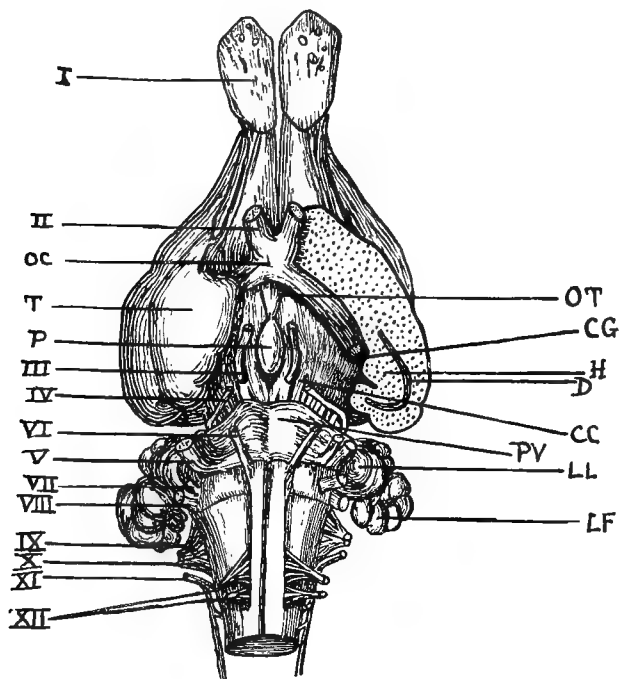
(3) Remove the brain from alcohol and lay it down with dorsal side up. The following parts are easily distinguished: The *cerebral hemispheres*, beneath which are the *olfactory lobes*, and back of which is the *cerebellum*, and the *medulla oblongata*, tapering posteriorly to the spinal cord. Between the cerebrum and the cerebellum may be seen the *pineal body* and the *optic lobes*. Draw dorsal view of brain ($\times 1$). From the ventral side of the brain may be seen the twelve pairs of cranial nerves, which may be more easily found by reference to the drawing below. Find the roots of each of these, and tabulate them, giving the uses of each.

Compare the brain of the rabbit with that of the pigeon. (See page 189.)

If the brain has been removed carefully, the ventral side will resemble the cut on the following page. On the right side of the cut the temporal lobe has been removed to show the *corpus geniculatum* and several other parts that would otherwise be covered.

By putting the brain of the rabbit in the same position as the one shown in the cut the various parts may be found and drawn.

Lepus cuniculus. The ventral surface of the brain of the rabbit ($\times 2$).—After MARSHALL.



CC, crus cerebri. CG, corpus geniculatum. D, descending cornu of left lateral ventricle. H, hippocampus major. LF, floccular lobe of cerebellum. LL, lateral lobe of cerebellum. OC, optic chiasma. OT, optic tract. P, pituitary body. PV, pons Varolii. T, temporal lobe of cerebral hemisphere. I, olfactory lobe, with roots of olfactory nerves. II, optic nerve. III, third nerve, or motor oculi. IV, pathetic nerve. V, trigeminal nerve. VI, sixth or abducent nerve. VII, facial nerve. VIII, auditory nerve. IX, glossopharyngeal nerve. X, pneumogastric nerve. XI, spinal accessory nerve. XII, hypoglossal nerve.

(4) Remove a nerve and dissect it as in the bird. See page 189.) Find the parts and make a diagrammatic sketch of a section running from cornea back through the optic nerve.

IV. THE HEAD.—(1) Under the lower jaw find imbedded in the muscles the *salivary glands*, pink, roundish bodies. Find four pairs, the *parotid*, the largest, just under the ears; the *submaxillary*, just in front of the parotid; the *infra orbital*, just below and in front of the eyes; and the *sublingual*, under the tongue near the meeting of the bones of the lower jaw. Of what value are the salivary glands? Find their ducts leading to the mouth. Carefully remove the *tongue*. Note its connection with the esophagus. At the base of the tongue find the triangular bone, the *hyoid*, embedded in the muscles. Was it attached to any other bone? Of what use is the hyoid? Study the *tongue*. Note the muscular base, the furred surface and the shape. Has the surface the same appearance in different parts? Explain. Examine the surface for evidences of taste bulbs, or *papillae*. A section of a portion of top of tongue would perhaps show this latter. Draw surface of tongue. Of what value to the rabbit is the tongue?

(2) Remove the muscles from the jaws. Note their thickness and mode of attachment. Explain the advantages of such form and arrangement.

(3) Remove the lower jaw. Notice especially the nerves which run into the jaw from the head. Find tube leading from the mouth into the ear, the *Eustachian tube*. Note the opening from the nasal passage into the mouth, the *pharynx*. Notice the teeth of the upper and lower jaws. How many

■

in the back part? These are the jaw teeth or *molars*. Notice how they articulate with each other. Note the front teeth, *incisors*, above and below. Note how they articulate, and how they are used. Do you think the rabbit is likely to have toothache? Note the area without teeth. Is this an advantage? Why? Study the roof of the mouth. Are the corrugations of any value? Draw upper surface of mouth, showing and naming the parts studied.

V. (1)—THE SKELETON.—(a) Note the divisions of the skeleton into *skull*, *spinal column* and *appendages*. Sever the head from the cervical vertebrae, noting the method of articulation of the *condyles* of the head and the *atlas* of the spinal column.

(b) Replace the bone which was cut out to remove the brain and study the bones of the skull. The following bones may be easily seen: the *occipital*, through which the spinal cord goes; the small *interparietal*, between the two larger *parietals*, larger and curved; the *frontals*, the *nasals* above the nostrils, and the *premaxillaries*, from which the incisor teeth grow. How are the bones of the skull connected? Note the bones on the outer boundary of the eye orbit, the *zygomatic* process. Draw upper view of the skull.

(c) View the skull from the lower side. The maxillary bone is behind the premaxillary, and contains the molar teeth. Then follow several small bones, which terminate at the ear bone and unite with the *squamosal*, the larger side bone which joins the occipital. Study the ear bone, the *tympanic*; cut open the coil and note the winding bone, the *cochlea*, through which sound is conveyed to the inner part of the ear and finally to the auditory nerve. What is the value of such a bone? Between the tympanic membrane

and the cochlea find three articulating bones, the *hammer*, *anvil* and *stirrup* which convey the sound from the outer to the inner ear. Of what peculiar value is the external ear? In different parts of the skull note small openings through which nerves pass from the brain. These are *foramen*. A prominent one is seen on the inner surface of the eye socket.

(2)—THE SPINAL COLUMN—(a) Identify the following divisions of vertebrae: *cervical* (neck), the *thoracic* (rib-bearing), the *lumbar* (without ribs), the *sacral* (united vertebrae of pelvis), and *caudal*, or tail. Count the number of vertebrae in each. Study the ribs in the thoracic region and compare them with the projections or *transverse processes* of the lumbar vertebrae. Of what value are the ribs? The processes? Why would it not be better to have ribs the entire distance?

(b) Remove the vertebra bearing the sixth pair of ribs by cutting through the cartilaginous joints. Find the *centrum*, the *neural arch* containing the spinal cord, the *ribs*, and the *cartilage* which unites the ribs with the sternum. Study the cartilaginous packing at each end of the vertebra. Of what use is it? Does the rib grow out of the vertebra? Is it movable? Explain the attachment. What is the advantage or disadvantage of having movable ribs? Study the attachment of the ribs to the *sternum*. What is the nature of the sternum? Is it divided into segments? How many ribs are attached to it? Sketch the sternum with its attachments. Make drawing of the typical segment just studied ($\times 1$).

(c) Remove the fifth vertebra of the lumbar region. Study as before the centrum, neural arch, and the neural

spine above it, the transverse processes corresponding to the ribs and the articular processes on the dorsal side. Compare these parts in size and strength with the corresponding parts of the first vertebra studied, and give reasons for your conclusions. For what are the processes used? Compare the cavities above and beneath the centrum with the neural and haemal arches of the fish. (See page 159.) Draw the posterior end view of the vertebra under consideration.

(d) With a scalpel carefully cut away the neural arch and expose the spinal cord. Notice the openings, *sinuses*, in the sides of the vertebrae where the spinal nerves leave the cord. Remove the cord, noticing carefully which is anterior and which posterior parts. Study the origin of the spinal nerves in the *anterior* and *posterior roots*. Draw the segment of cord thus studied.

(e) Remove the flesh and the hind limbs from the pelvic arch and study the bones which compose it. How many bones? How are they articulated? Are they vertebrae? Could they have been specialized from the typical vertebra just studied? Explain what changes have taken place, and give reasons. Draw dorsal and ventral views of the pelvic arch.

How many bones in the caudal region? Are they vertebrae? Why?

(3)—THE LIMBS.—(a) The bones of the limbs are easily distinguished. In the front limbs the shoulder girdle can be traced, consisting of *scapula* and *clavicle*, a small, almost cartilaginous bone, extending through the flesh and uniting with the sternum. Do you find the *coracoid* bone? What office does it fill? (It is a process extending from the *scap-*

ula over the end of the humerus). Other bones beginning with the shoulder are the *humerus*, the *radius*, the smaller; and the *ulna*, the larger; below the elbow, the *carpal*, wrist bones; the *metacarpal*, or palm bones; and the *phalanges*, or toes. Study and describe the articulation in each of these bones. Make a diagrammatic drawing of front limb. Compare with wing of bird.

(b) In the hind limb the bones are equally easy to distinguish. Beginning with the pelvic girdle, find the *femur*, with its deep ball and socket joint; the *tibia* and *fibula*, below the knee joint, which is covered with a *patella* or knee cap; the *tarsus*, the *metatarsus* and *phalanges*. Draw a diagram of hind limb. Compare with leg of bird.

CLASSIFICATION.—Adapted from PACKARD.—The rabbit belongs to the family *Leporidae*, order *Glires*, and class *Mammals*.

The class mammals contains the following orders which can be fully worked out by reference to a larger Zoölogy.

Orders of Mammals.

Subclass I. With long toothless jaws like a duck's bill, young carried in a mammary pouch. *Ornithodelphia*.

Order 1. Monotremata. Duckbill.

Subclass II. Young born alive, but kept for awhile in a pouch. *Didelphia*.

Order 2. Marsupialia. Opossum.

Subclass III. Young born of considerable size and perfect development; nourished before birth through a placenta; brain in most cases possessing convolutions. *Monodelphia*.

Order 1. No incisor teeth; sometimes entirely toothless.

Bruta: *Sloth*.

Order 2. Rodents; with large incisor teeth. Glires: *Rat*.

Order 3. Fore limbs often adapted for burrowing; teeth sharp; feeding on insects. Insectivora: *Mole*.

Order 4. Fore limbs long, webbed, and adapted for flying.

Order 5. Cetaceans; body fishlike in shape; no hind limbs.

Cete: *Whale*.

Order 6. Body fishlike in shape; teeth like those of ruminants.

Sirenia: *Manatee*.

Order 7. Snout prolonged into a proboscis.

Proboscidea: *Elephant*.

Order 8. Long curved incisor teeth; feet with pads; toes hoofed.

Hyracoidea: *Hyrax*.

Order 9. Toes hoofed.....Ungulata: *Horse, Ox*.

Order 10. Teeth pointed for tearing flesh; claws large.

Carnivora: *Dog, Cat*.

Order 11. Nails usually present; walking on all fours; or using fore legs as hands; or erect and walking on the hind legs.

Primates: *Monkey, Ape, Man*.

SUMMARY.—The rabbit is taken as a type of the class mammals, or milk givers. It is a highly specialized animal. Make a list of the specializations you have observed, and tell the advantages or disadvantages of each. Is it solitary or gregarious? How does this benefit it? Has the rabbit a good method of defense against enemies? What method of escape does it select? What animals are its enemies? Since it is hunted by so many animals, and has such a poor means of defense, why does it not become extinct? (Reproduction.) What preparation does it make for its young? Does it care for its young? What is its food in summer? In winter? Is it injurious or beneficial to man? Why?

APPENDIX

I. THE COMPOUND MICROSCOPE

The following simple outline is given for the use of beginners with the microscope. It may be enlarged by the teacher:

PARTS.

I. STAND.

1. Base: The part on which the instrument rests.
2. Joint: Allows the upper part to move on a hinge.
3. Body: The part above the joint.
4. Adjustments:
 - a. Coarse, upward movement accomplished by the rack and pinion.
 - b. Fine, accomplished by the thumbscrew usually at the top of the stand.

II. STAGE.

1. Floor: The surface of the stage bearing the clips or holders.
2. Diaphragm: Contrivance under the opening in the stage, to regulate the amount of light transmitted.
3. Mirror: A mounted adjustable mirror situated below the stage to reflect the light through the object into the objective.

III. BARREL.

1. Eyepiece or Ocular: The lens at the top of the draw tube.
2. Draw Tube: The tube capable of being withdrawn, containing the eyepiece at the upper end and the objective below.
3. Objective: The lenses at the lower end of the draw tube, ordinarily ranging in focal distance from 1 inch to 1-6 inch. They are named from this focal distance.
4. The Revolving Nosepiece: A contrivance for holding two or three objectives for immediate use.

SUGGESTIONS ON THE USE OF THE MICROSCOPE.

1. Put the slide on the stage under the clips with the object to be studied over the opening in the diaphragm.

2. See that the lens is in the proper position in the barrel (always use the low power, *i. e.*, the longest focal distance unless otherwise directed), and with the coarse adjustment bring the objective close to the cover glass. Place the eye over the eyepiece and look for the object; lift the barrel with the coarse adjustment until the object on the slide appears clearly defined. It is now said to be in focus.

3. After the object is in focus, use the fine adjustment to clear up the different parts of the specimen. Move the specimen until all the parts have passed the field of the microscope. It will be noticed that the image is inverted as well as magnified. An explanation for this should be sought from the teacher or from a good text on the microscope.

4. The compound microscope is a delicate instrument,

and should be handled with extreme care. It would be well to *memorize* the following cautions and try to use them until they become habitual:

Never touch the lens of the eyepiece or objective with the hand. Cleanse them with a camel's-hair brush or a piece of soft silk.

Never move the lens downward while the eye is at the eyepiece, *always focus upward*, especially if you are using the coarse adjustment.

Before leaving a microscope, rub it dry and clean it with a piece of flannel or chamois skin and put it in its proper place. Never leave a microscope in the direct rays of the sun or where dust may gather on it.

II. HOW TO USE THE TABLES OF CLASSIFICATION.

To a student who has not used the Tables of Classification, the following suggestions may be found helpful. It will be easier to trace to its family the type specimen which has been thoroughly studied as its characteristics are fresh in the mind.

Some of the tables have the different divisions in figures, and some have letters. The difference between these will be apparent at a glance.

These tables do not carry the classification further than the families; classification into genera and species can be made by consulting specialists on the different classes of animals.

Suppose that we have a beetle which we desire to trace to its proper family. We proceed as follows:

Look at the specimen carefully, noting its external features.

Read the first line A (see page 59).

If your specimen agrees with this *exactly*, then its family is found somewhere under A, the subdivisions of which are set in farther to the right on the page.

If your specimen does not agree with A, then, omitting all the subdivisions of A, go to AA on page 64, and compare that description with your animal. If AA describes the specimen correctly, then the family is under this group.

Suppose the specimen belongs under A.

Read B. If this is true, the proper family belongs under this heading.

Read C. If this is true of your specimen in every particular, it belongs to the group *Phytophaga*, which contains several families.

Read D. If this is correct the specimen belongs to the family *Spondylidae*; if it is not true, look at DD, which is coördinate with D and includes the families described in E and EE.

Suppose your specimen does not belong under C, then read CC at the bottom of the page. If this be true, trace to the proper families in the manner above described.

In like manner, if B is not true of your specimen, turn to BB on page 63. If this description be true, read C, D and E to find one that is true. If you find nothing there which fits your specimen, turn to CC on page 64 and follow these descriptions in the same way.

In the tables where figures are used the same general plan may be followed. Read the descriptions until you find one that coincides exactly with the specimen in your hand.

The difficulties in the way of using these tables, which may at first seem great, will be easily overcome by tracing three or four specimens through to their proper families.

III. REAGENTS IN COMMON USE.

Only the most common reagents are given, as it is supposed that the teacher will have access to technical books for all delicate experiments and tests.

ALCOHOL.—As commonly obtained for laboratory purposes, alcohol is ninety-five per cent. pure. This may be diluted to the required strength by calculating the amount of water to be mixed with ninety-five per cent. alcohol to produce the amount of liquid required. It may be obtained for school purposes free of internal revenue by complying with certain formalities required by law. Such alcohol is of the best quality—ninety-five per cent. generally—and can be obtained at a great reduction from the regular retail price. For information address Secretary of the Treasury, Washington, D. C.

FORMALIN.—This is a hardening agent, which has much the same effect on hardening tissue that alcohol does, except that it expands the tissue slightly. For all general purposes it is equal to alcohol and has the additional advantage of being much cheaper. It is used in strength from one to two per cent solution in water.

OSMIC ACID.—One and one-half to two and one-half per cent. solution used for killing microscopic animals. It should be kept in the dark and should be diluted with water when used.

BORAX CARMINE (*Grenacher's*).—Solution of powdered carmine and borax in water and alcohol. The beginner should order it in solution, and not dry. It is used for staining, and is perhaps the most serviceable for general use. It may be used cold or at a temperature of 50° C.

MAGENTA.—Solution of $\frac{1}{2}$ grm, of roseine in 1 liter of water, add 5 c.c. absolute alcohol. It is used to stain fresh preparations for immediate and temporary use.

OIL OF CLOVES.—A clearing agent. Used to clear a specimen of alcohol before permanent mounting. Should clear the object, but not stay on the slide too long, or it will make the section brittle.

TURPENTINE.—May be used as a clearing agent. Also used to remove paraffin from sections before mounting.

SALT SOLUTION.—Normal solution of 7.5 grms. common salt in liter of water. Used for examining living or freshly killed tissues.

GLYCERINE.—Used pure or diluted with water for mounting objects for microscopic study.

CANADA BALSAM.—The common name for balsam fir of commerce. May be used as bought from druggist or evaporated to dryness, powdered and dissolved in alcohol or turpentine. It is the most commonly used medium for mounting stained sections for microscopic study.

PARAFFIN.—Used for imbedding objects for permanent mounting. Paraffin with melting point 56° C. may be used alone or mixed with paraffin the melting point of which is 40° C.

SHELL-LAC.—Dry shell-lac dissolved in absolute alcohol, allowed to stand for some time is ready for use. Used to fix the sections to the slide for mounting.

COLLODION.—Mixed with an equal part of oil of cloves. Used for fixative in the same way as shell-lac and alcohol.

IV. METHODS OF PREPARING MATERIAL FOR MICROSCOPIC EXAMINATION.

In fully equipped laboratories the teacher and student will have at command special books on microscopical technique and methods, but for the benefit of those who may not have access to such books the following brief suggestions are given:

The particular methods to be used depend upon the nature of the tissue and the kind of observation to be done. As a rule, the softer tissues have to be hardened, and the harder softened or cleaned, before making permanent mounts.

1. KILLING: The method of killing depends upon the animal, but as a rule that method should be used that will leave the body in natural form with tissues uninjured. Chloroform for the crustaceans and vertebrates, potassium cyanide for the insects, spiders, and centipedes, warm water for the mollusks and earthworms, can in general be recommended; and for lower forms special methods may be found by consulting books on histology.

2. HARDENING: For ordinary purposes alcohol is the best hardening agent. The specimen should be placed first in weak solution, about sixty per cent., then in seventy per cent. then eighty per cent. and ninety per cent. and finally, before beginning the work of imbedding, it should be placed in absolute or one hundred per cent. alcohol. Considerable alcohol should be used each time, except the last, and the

time for the entire process on ordinary tissue should extend over two or three days.

3. STAINING: If the specimen is for temporary observation, the stains magenta or methylene blue may be used; but for permanent mounts it is better to use alcoholic stains, of which borax carmine (Grenacher's) is perhaps the most desirable. The object should be placed in the stain from sixty per cent alcohol, and should remain in the stain until saturated to the degree of color desired. The length of time required for this will have to be determined by trial and depends upon the size of the specimen, as well as its penetrability. After staining, the object should be run up to ninety per cent. and then to absolute alcohol, as directed in 2, on hardening. Alcohol is useful for removing an excess of stain, used with hydrochloric acid (3 to 6 drops to 100 c.c of seventy per cent. alcohol) it will give a better result from staining with borax carmine. The stained object should be left in the acid alcohol for a time varying from one-half hour to three hours.. This staining may be done if desired after the sections have been cut and mounted.

4. CLEARING: After staining, the alcohol must be removed by oil of cloves or turpentine. A short time only will be necessary for this, and the specimen is then ready for imbedding.

5. IMBEDDING: For this purpose paraffin, melting point 50° C., should be melted and kept in a water bath at not above 60° C. A softer paraffin will be found better sometimes, especially in cold weather. Drop the specimen to be imbedded in this paraffin, and allow it to remain until it is thoroughly permeated with paraffin. The length of time varies from thirty minutes to an hour.

Make a small paper trough, considerably larger than the object to be imbedded; fill it with the melted paraffin, and drop the saturated object into it in the exact position desired for cutting the sections. When this is done cool the paraffin as quickly as possible by putting it in a basin of cold water, being careful to keep the water away from the paraffin until it is hard enough to prevent injury. When it is thoroughly hardened, the paper may be removed and the object is ready for cutting into sections. It has been suggested that glass tray salt cellars will accomplish the work of the paper trough.

6. SECTIONING: The paraffin block may be fixed on the microtome by the method most convenient, and the sections cut of the thickness desired. The particular method of manipulating the microtome depends upon the structure of the instrument.

MOUNTING: Prepare a glass slide as follows: The slide should be free from flaws, and should be ground at the edges. See that it is thoroughly dry, and has a temperature of about 60° C. Spread on the center of it a thin layer of cement, or a diluted alcoholic solution of shell-lac, and allow the alcohol to evaporate almost to dryness. Next spread a bit of oil of cloves or turpentine on the slide, and place the section on the moist slide. Allow the slide to remain for a while in a warm place free from dust, in an oven if convenient, until the section is thoroughly cemented to the slide. Now put the slide in turpentine, or put turpentine on the slide and allow it to remain until all the paraffin is dissolved out of the tissue.

When this is done the slide should be taken out of the turpentine, a drop or two of balsam let fall on it, the size

of the drop depending upon the size of the section, and a thin clean cover glass placed lightly on top of the balsam. Keep the slide in a warm place until the cover glass sinks down flatly on the slide, and put the slide away for drying. After drying for several days the balsam will become hard and the slide may be cleaned with alcohol and the proper label placed on the side. The label should contain the name of the object, the thickness of the section, and the stain used on one side of the cover glass; and the name of the preparation and the date, on the other. Then put the slide away in a slide box, properly labelled.

GLOSSARY

Words that are clearly explained in the text are not defined here but reference is made to the page where the explanation occurs.

Adduc'tor, 142.

A'erated, mixed with air. The water is aerated before supplying the gills.

Al'ulet, 74.

Ambula'cral, (Lat. Ambulare—to walk). Pertaining to the walking tube feet or their areas.

An'al. Situated near the anus or in the posterior region.

Anal'ogous. Applied to organs in animals that are put to similar uses but are different in origin and structure, as the wings of a grasshopper and bird.

Anas'tomosing. Mixing as in the mixing of veins of different directions.

Annel'ida. A group of animals with bodies composed of similar segments without jointed legs.

An'nulated. Surrounded by

bands or rings of different colors.

An'nulus, 126.

Ap'erture, 144.

Appendic'ulate. Having small appendages.

Apposi'tion. Placed side by side.

Ap'terous. Without wings.

Aquat'ic. Living in water.

Arach'nida, (Gr. *Arachne*—a spider). A class of Arthropods.

Arthrop'oda, (Gr. jointed feet). A branch of animals distinguished by having segmented appendages.

Asymmet'rical. Not symmetrical.

Au'ditory. Pertaining to the sense of hearing.

Bar'bules, 179.

Beak. The sucking tube of some Hemiptera.

- Bicus'pid. Composed of two cusps or flaps.
- Bi'fid. Two divided or folded.
- Bira'mous. Two branched.
- Bi'valve. A mollusk having two shells hinged together.
- Blas'toderm, 120.
- Boot'ed. Having an undivided, horny, bootlike covering. Birds sometimes have booted *tarsi*.
- Bran'chia, pl. branchiae. Respiratory organs for breathing air from water.
- Branchios'tegal. Pertaining to membrane covering the gills of fishes.
- Cae'cal. Pertaining to baglike projections from alimentary canal.
- Cap'itate. Headlike in form.
- Car'apace, 95.
- Car'inate. Shaped like the keel of a boat.
- Carot'id. One of the principal arteries of the neck.
- Cau'dal. Pertaining to the tail.
- Cephal'ic. Pertaining to the head.
- Cephalotho'rax, 88.
- Cer'ci, 27.
- Cerebel'lum. The posterior lobe of the brain.
- Cer'ebrum. The anterior portion of the brain.
- Chi'tin. The horny outside skeleton of Arthropods.
- Cho'roid, 158.
- Cir'rus. A hairlike projection.
- Cla'vate. Thicker toward the top.
- Cla'vicle, 174.
- Cloa'ca, 166.
- Coelentera'ta, (Gr. Hollow Intestine). A branch of the animal kingdom in which the entire digestive canal is one tube.
- Co'lon, 32.
- Coleop'tera, (Gr. Sheath-winged). An order of insects which have hard outer wings.
- Columel'la, 145.
- Com'missure. Nerve fibers connecting ganglia or other parts of the nervous system.
- Con'fluent. Uniting and running together.
- Coniros'tral. Pertaining to a strong conical bill.
- Con'nate. Growing from one base.
- Convolu'tion. Irregular folding of the brain of vertebrates.
- Cor'acoid, 174.
- Cor'puscles, 169.
- Cos'tal. Relating to the ribs or sides.
- Cra'nial. Relating to the skull.
- Ctenid'ia. Gills of mollusks.
- Cu'bitus, 41.
- Cul'men. The dorsal ridge of the bill of a bird.
- Cu'neus. A wedge-shaped part.

- Decid'uous.** Pertaining to being shed or cast off, as the gills of a frog.
- Del'toid.** Triangular in shape.
- Di'aphragm.** Muscular partition between chest and abdomen as in mammals.
- Dip'tera, (Gr. Two Wings).** An extensive order of insects that have but two fully developed wings.
- Duode'num, 183.**
- Du'ra ma'ter, 171.**
- Ec'toderm, 120.**
- Ec'tosarc, 107.**
- El'ytron, pl. Elytra.** The hardened outer wings of some insects.
- En'doderm, 120.**
- En'dosarc, 107.**
- Envi'ronment.** The conditions surrounding an animal which influence its growth and development.
- Epim'eron, pl. epimera.** The part just outside of the basal segment of an appendage in Arthropods.
- Esopha'geal.** Pertaining to the esophagus.
- Excre'tory.** Having the power to excrete or throw off.
- Exten'sor.** The muscle that causes extension.
- Ex'serted.** Projecting beyond some other part.
- Fa'cet, 28.**
- Fe'mur, pl. femora.** The thigh bone.
- Fil'iform.** Having the shape of a thread or filament.
- Fissiros'tral.** Having the bill cleft beyond the horny part.
- Flabel'late.** Fanlike in shape.
- Fora'men.** A small opening.
- Gan'glion.** A collection of nerve cells through which nerve fibers pass.
- Gas'tric car'ca.** Blind sacs extending from the stomach.
- Genic'ulate.** Bent abruptly at an angle.
- Go'nys.** Under outline of a bird's bill from the tip to the point of union of upper and lower mandibles.
- Grub, 57.**
- Gu'la.** The part of the neck next to the chin. In insects the plate under the submentum.
- Hae'mal.** Pertaining to the heart or blood vessels.
- Ham'uli, 67.**
- Haustel'um.** The sucking tube or proboscis of insects. It is made of modified mouth parts.
- Hemip'tera, (Gr. Half Wings).** An order of insects having outer wings part hard and part membranous.

- Hepat'ic. Pertaining to the liver.
- Heteroc'era. A group of Lepidoptera having the antennae variable in form.
- Heterop'tera. A group of Hemiptera having base of front wing thickened.
- Hi'bernate, 85.
- Homol'ogous. Having similar origin and structure but different use, 96.
- Homop'tera. A group of Hemiptera having wings of similar texture.
- Hymenop'tera, (Gr. Membranous Wings). An order of insects having both pairs of wings membranous.
- In'fra. Below or posterior to.
- Ima'go, 42.
- Keel. A projecting ridge on the sternum of birds.
- Lar'va, 42.
- Lig'ament, 182.
- Lepidop'tera, (Gr. Scale Wings). An order of insects having wings covered with scales.
- Malpi'ghian Tubes, 32.
- Mam'mary Glands. Milk-producing glands of mammals.
- Man'tle, 140.
- Medul'la oblonga'ta. Enlargement of the spinal cord below the brain.
- Mes'oderm, 120.
- Mes'enteries. The thin membranes holding the intestines to the walls of the abdomen.
- Mesoster'num. Middle segment of the sternum of the thorax.
- Met'amere. One of the similar divisions of the body of an animal, same as somite.
- Metaster'num. Last segment of the sternum of the thorax.
- Metamor'phosis. In insects the passing of the larva through more or less complete changes to the adult form.
- Morphol'ogy. The study which deals with the forms and structure of animals.
- Myriop'oda, (Gr. Thousand Legs). A class of Arthropods having many jointed legs borne upon similar segments.
- Nau'plius. The larval stage of some of the crustaceans.
- Nephrid'ia, 128.
- Neu'ral. Pertaining to the nerves or the nervous system.
- Neurop'tera, (Gr. Nerve Wings). An order of insects having membranous wings with numerous veins.
- Ni'ctitating Membrane, 178.
- Noctur'nal. Active by night, as many of the moths.
- Nymph, 79.

- Occip'ital condyle, 199.
- Olfac'tory. Pertaining to the organs of smell.
- Op'tic. Pertaining to the organs or nerves of sight.
- Os'cines. The group of birds that sing.
- Orthop'tera, (Gr. Straight Wings). An order of insects which have straight outer wings.
- O'viduct, 33.
- Ovipos'itor. An organ composed of several specialized parts of the abdomen with which many insects place their eggs.
- Pal'lial, 140.
- Papil'lae, 164.
- Paraglos'sae, 55.
- Pata'gia, 46.
- Pec'tinate. Shaped like a comb, with toothed edges.
- Pe'dal. Pertaining to the foot.
- Ped'icel, 65.
- Pelag'ic. Living in the surface waters of the ocean.
- Pericar'dial. Situated around the heart.
- Peritone'um, 153.
- Phar'ynx, 165.
- Pia mater, 171.
- Pig'ment cells. Cells that give coloring to the animals.
- Pi'neal gland. A glandlike body in the brain of vertebrate animals. It is sometimes connected with a rudimentary eye called the pineal eye.
- Placen'ta. The vascular appendage connecting the young to the parent before birth.
- Plas'ma, 169.
- Pleu'ral. Relating to the pleurum, 23.
- Plex'us. A network of vessels, nerves or fibers.
- Plumose'. Feathery.
- Porrect'ed. Extended horizontally.
- Preda'ceous. Living by prey.
- Pri'maries. The long feathers on the last joint of the bird's wing.
- Probos'cis. In insects a hollow sucking organ usually made by the combining of several mouth parts.
- Prono'tum, 23.
- Proster'num. The first division of the sternum of the thorax of insects.
- Protrus'ile. Capable of being protruded or thrust out.
- Pulvil'li, 75.
- Pu'pa, 42.
- Pygid'ium. The tail plate of crustaceans and insects.
- Pylo'ric caeca, 154.
- Quad'rate bone. The small bone between the lower jaw and the base of the skull in most vertebrates below mammals.

Rachiglos'sate. Having three longitudinal rows of teeth on the radula.

Ra'dius, 41.

Rad'ula. Tongue of a gastropod mollusk.

Renal, 167.

Retic'ulate. Having veins or fibers crossing like network.

Ret'ina, 158.

Retract'or, 142.

Rhopaloc'era. The group of Lepidoptera having clubbed antennae—butterflies.

Ric'tal. Pertaining to the corners of the mouth.

Ros'trate. Beaklike.

Sclerot'ic, 158.

Scutel'lum, pl. scutella. Transverse scales on the tarsi and toes of the bird.

Sec'ondaries. The feathers on the second section of the wing of a bird.

Sep'tum, pl. septa. Radial partition of a coral cup. A transverse partition in worms.

Si'nus. A detached vessel or canal. A cavity.

So'mite, 26.

Sper'maries. The reproductive glands of the male animal.

Spir'acle, 24.

Spu'rious quill. Outer primary quill when much reduced.

Stridula'tion. The making of

sound by rubbing hard parts together as in insects.

Su'bulate. Awl-shaped.

Taenioglos'sate. Relating to a long narrow tongue of mollusks bearing seven rows of teeth.

Teg'ula, pl. tegulae, 66.

Teg'men, pl. tegmina. The outer wing of certain insects.

Ter'gum, 23.

Tertial feathers. Growing on the innermost division of a bird's wing.

Thy'mus. A ductless gland in the region of the throat of many vertebrates.

Toxoglos'sate. Pertaining to the tongue of gastropods containing poison fangs.

Tra'cheae. Tubes of the respiratory systems of Arthropods.

Tym'panum. The eardrum or membrane through which sound is conveyed.

Um'bo, pl. umbo'nes. The hump above the hinge on a bivalve shell.

Unira'mous. Consisting of one branch.

Urinif'erous Tubules, 44.

U'rostyle, 174.

Vas def'erens, 33.

Ver'miform, 201.

Outlines of Botany

FOR THE

HIGH SCHOOL LABORATORY AND CLASSROOM

BY

ROBERT GREENLEAF LEAVITT, A.M.

Of the Ames Botanical Laboratory

Prepared at the request of the Botanical Department of Harvard University

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